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IRRIGATION

IN THE

UNITED STATES.

A REPORT PREPARED BY RICHARD J. HINTON,

UNDER THE DIRECTION OF THE

COMMISSIONER OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1887.

LETTER

FROM

THE COMMISSIONER OF AGRICULTURE,

TRANSMITTING,

In response to Senate resolution of August 4, 1886, a report on irrigation.

DECEMBER 17, 1886.—Referred to the Committee on Agriculture and Forestry, and ordered to be printed.

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
COMMISSIONER'S OFFICE,
Washington, D. C., December 15, 1886.

SIR: I have the honor to transmit herewith, in accordance with a resolution of the Senate of August 4, 1886, certain information on the subject of irrigation which has been gathered and prepared for publication by this Department.

Very respectfully, your obedient servant,

NORMAN J. COLMAN,
Commissioner of Agriculture.

Hon. JOHN SHERMAN,
President pro tempore of the United States Senate.

IRRIGATION IN THE UNITED STATES—ITS EXTENT AND METHODS, WITH DIGEST OF LAWS GOVERNING WATER SUPPLY.

By RICHARD J. HINTON.

THE ARID REGION.

The inquiry into the progress and present condition of irrigation in this country has necessarily involved a consideration of the extent and character of the area within which the annual rainfall is not sufficient for the industrial uses of the people. Such an inquiry, broadly defined, has involved the extent of the fall of rains or snow within the area indicated; also the evidence obtained as to increase or decrease of precipitation resulting from agricultural settlement or of pastoral occupation, the increase of humidity of earth or air, the destruction of the timber mainly by its use for settlement purposes, the effect of the destruction of the native grasses and the substitution of cultivated varieties; also the sources of water supply, their character, uses, conservation, the means, natural and artificial, employed for their distribution, and what has been and is being accomplished in the way of artificial methods of water distribution and economy, and the laws and customs pertaining thereto.

Incidentally, the questions arising from deforesting, on the one hand, and of extensive arboriculture, on the other, are related to the inquiry, and have been brought out to some extent. The effort has been to obtain, by means of personal letters and by circulars, addressed to irrigators, arboriculturists, engineers, land owners, colonists, and all other persons known to be actively interested, the actual facts upon these subjects, so far as they could be supplied from observation, experience, experiments, and realized results. This effort has been measurably successful. It has brought together a mass of facts and well-considered observations that shed much light on the questions involved, giving a broader idea of the importance of irrigation, and adding greater value to a very large area of the United States, of whose agricultural capabilities but small account has heretofore been taken. It will be developed by the facts herein presented that the area of the irreclaimable arid lands within the boundaries of the Union is, comparatively speaking, quite moderate in its extent. There is, however, a very large area, embracing at least one-third of our total land surface, wherein the water supply, whether subterranean and surface-flow or in the form of precipitation, is both inadequate and irregular in character.

The eastern boundary of this great area may at present be assumed to be the one hundredth meridian of west longitude. The western boundary may be in part placed at the Pacific Ocean, though more accurately the Coast Range of California would be the line. The northern boundary is the British territorial line west from the one hundredth degree to the summit of the Sierras, or the one hundred and twentieth meridian. Following the summits of the main range, the northwest line would deflect to the central portion of Oregon, following the southwesterly bend of the mountains down to the northern boundary of California. The southern limit of this dry area would be the northern line of Mexico, and thence south by east, along the Valley of the Rio Grande, down to the Gulf of Mexico. The area then, east and west, through its central and larger portion, runs from the one hundredth meridian to the one hundred and twenty-fourth degree of west longitude, and in its greatest prolongation north and south from the forty-third to the twenty-seventh degree of latitude. In its more northern portion it runs east and west from the ninety-eighth to the one hundred and twentieth degree of west longitude. The larger portion from north to south is embraced between the thirty-second and forty-third degrees of latitude. These lines cover about one-half of the States of Kansas and Nebraska and the Territory of Dakota, the whole of the States of Colorado and Nevada, with four-fifths of California, one-third of Texas, and about one-third of Oregon; also the Territories of Wyoming, New Mexico, Utah, Montana, Idaho, and Arizona, with at least one-third (east of the mountains) of Washington Territory. This embraces about one-third of our whole territorial surface, inclusive of Alaska. How much of the latter-named Territory may be wholly or partially arid or desert in character cannot yet be estimated. The east and west lines of this dry region, then, are, in the widest section, over 1,300 miles apart, and in its greatest length, the northern and southern limits are about 1,000 miles apart. If the whole region were compactly arranged it would make a block about 1,000 miles square. The area thus indicated may be subdivided again into three broad divisions, as follows:

(1) The plains region, running north and south from the British American line to the lower portion of the Rio Grande Valley in Texas, and east and west from the one hundredth to the one hundred and fifth degrees of west longitude. This division may be broadly declared to have a general rise and altitude of from 1,500 to 5,000 feet, though it will fall below that at either end of the area. It is but sparsely supplied with streams, which are mainly fed from mountain sources; the annual precipitation is nearly everywhere below a reliable amount for economic uses. In the central portion this precipitation will not, under favorable conditions, exceed 18 inches per annum in the eastern part, and as we go westward it diminishes to an average of about 12 to 14 inches per annum.

In the southern (Texas) portion of this area the rainfall will somewhat exceed 20 inches on the east, decreasing until, on the northwest, it will reach only 8 or 10 inches in the most favorable seasons. In the northern or Dakota portion the average is more evenly maintained. This division will include the western half of Kansas and Nebraska, one-third (or the eastern foot-hills and plains region) of Colorado, the major portion of Dakota, the eastern half of Wyoming Territory, and one-third or more of the Indian Territory and Texas, with about one-fourth (or the eastern part) of New Mexico. It is drained by a number of streams, some of them of importance, and is bounded on the east and north by the Missouri River and its affluents, and by the Pecos and Cimarron Rivers on the west and southwest. Its soil is almost uniformly fertile. Natural grasses of most nutritious quality are found throughout its area. It is the most important grazing section of the West.

Large farming settlements are moving steadily and compactly westward from the eastern line. At various points in its western portion there are important farming communities, created mainly by the use of water as applied through irrigation ditches and by other means of storage and distribution. The Valley of the Upper Rio Grande, from the San Juan Range in Southern Colorado, to where the river debouches from New Mexico into Texas and becomes the boundary line between the United States and Mexico, has for many generations been the seat of extensive, if local and unsystematized, irrigation works. The Pueblo or town-dwelling Indians have for centuries practiced it. Since the Spanish conquest, in the sixteenth century, the mixed Mexican people who have inhabited this district have always been obliged to irrigate in order to cultivate. In these latter days our own more enterprising people are inaugurating and carrying on larger enterprises and projects, whose advantages are already perceivable.

(2) The second great division can be more distinctly characterized as the arid section of the United States. It lies between the one hundred and fifth and the one hundred and twentieth meridians, taking in the whole of our intra-mountain region, from the foot-hills of the Rockies to the lower slopes and foot-hills of the Sierras Nevada in California, and extending north and south from British America to Mexico. Within this area, except on the higher and arid heights of the ranges, principal or secondary, there is generally good pasturage for cattle. The natural grasses are sun-cured, and afford ample food and range for many million head of cattle.

The problem of water supply is, however, one for serious consideration. There are desert tracts and areas within this great region which are undoubtedly arid and desolate to the extent of irreclaimability. Their extent is a matter yet unsettled, especially in view of the great enterprises projected and in progress in both Colorado and California. Even the mountain plateaus, which, from altitude as well as aridity would seem to be undoubtedly sterile, may yet be found useful, not only in providing for cattle, but, possibly under systematic plans of forest-culture, they may be made the means of protecting the water sources and otherwise favorably modifying climatic and terrene conditions.

The defined outlines of this second division embrace the great basin section, of which Utah and its water reservoir—the great Salt Lake—are the dominating physical and geological features; the Colorado plateau region, which occupies the larger portion of Southern Nevada and Northern Arizona; the beautiful parks of the Rocky Mountains or the eastern flank and ranges of the North American Cordillera system; the table-lands of Southern Arizona, and the great valleys and basin formed on the north by the Columbia River and its important affluents in Eastern Oregon, Idaho, and Montana.

Arid and desert as this stupendous mountain system may seem to be, it will be found on examination to have large sections capable of agricultural uses, and also to hold within its borders such sources and supplies of water as, properly conserved, protected, and distributed, under the wise and conservative direction of the national and State Governments, will be found of ample utility for the purposes (1) of larger pastoral uses; (2) of more limited and localized, but still extensive, agricultural purposes; and (3) as storage and reservoir sources, from which at no distant day the life-giving waters may be conveyed to and distributed over vast areas, which even our present limited experiences prove to be convertible into fertile farms.

A glance at a good topographical map will indicate to the observant eye the areas under reference. For example, the central section of the Rockies (in Colorado, Wyoming, and a portion of New Mexico) contain the sources of important rivers. This hydrological area is extensive, as there are numerous lakes, some of considerable size, while the snow precipitation is also quite heavy. There is sufficient achieved already in Colorado under the stimulation of private need and profit to indicate what might be accomplished under larger direction.

The entire foot-hills region, a considerable portion of the plains rolling eastward to the one hundredth meridian and beyond, the important valleys of the Rio Grande, Platte, and Arkansas, with many small valley areas related thereto, might in a greater or less degree be reclaimed by means of the water supplies and snow precipitation found within the frontal range of the Rocky Mountains. Inquiry and examination will satisfy the inquirer that in the extreme west the higher Sierras yield from the snow precipitation alone an amount of water which, under proper engineering conservation and wise plans of distribution, carried out for the common weal rather than for corporate profit, would supply whole of the great valley and foot-hills region of Central and Southern California, now being so largely developed as a wheat and fruit growing region.

In the northern portion of our intra-mountain area the hydrological system, comprising the Columbia and Snake Rivers and their affluents, will give, it is asserted by many, a sufficient water supply for pasturage and agriculture. Of this section it is said that—

> East of the Cascade Mountains the climate and natural features of the country are very different from those of the great basin lying west of them, so that the popular divisions, Eastern and Western Oregon and Washington Territory, are warranted. In the eastern section the thermometer is much higher in summer and lower in winter than in the western section. The rainfall is only half as heavy. From June to September there is no rain. The winters are short, but occasionally severe. Snow seldom falls before Christmas, and, though it sometimes lies from four to six weeks, it usually disappears in a few days. The so-called "Chinook," a warm wind, blows periodically and melts deep snows in the course of a few hours.
>
> In Eastern Oregon and Washington spring begins in February, and lasts until the middle of May. At this season rain falls in sufficient quantity to give life to vegetation and insure good crops. The average temperature is 52°. The rainfall of the year does not average more than 20 inches. South of the Snake River it is not more than 15 inches, increasing gradually to the northward.

In the southern portion of this area, where the Colorado plateau descends to the valleys of the Gila, Colorado, and Rio Grande, forming the table-lands of Southern Arizona and New Mexico, there has already been utilized a water supply sufficient for cattle, and in several extended portions, as in the valleys of the Gila, Rio Verde, Salt, Colorado, Chiquita, San Pedro, and Santa Cruz Rivers, almost enough to meet the present agricultural and horticultural demands has been turned to account.

It may be estimated, then, that, of our whole intra-mountain region below the timber line as herein outlined, at least 60 per cent. affords fair pasturage, with sufficient watering places, though often at long intervals apart, and subject to various limitations, which are rapidly being in a degree overcome, and will hereafter largely disappear as more attention and skill are directed to the subject. The facts gathered from Utah and Nevada will show how large are the possibilities of improvement in this direction. No really accurate estimate can be made as to the proportion of this intra-mountain area that may be reclaimed for arable and horticultural purposes; but it is not extravagant to claim that when the accessible water sources shall be brought into use, one-fifth of its acreage (as already defined) may be so utilized. In a very large portion the per cent. will be quite small; in other portions it will greatly exceed the general estimate here made. It must be borne in mind that in both estimates the higher mountain sections, embracing at least one-fifth of the whole region, are excluded. Yet, on the summit of the highest plateau region in Northern Arizona, for instance, cattle are successfully wintered at an altitude of from 7,000 to 10,000 feet above the sea.

(3) The third division, which might fairly be ranked first in point of interest, embraces the Pacific coast region from the western slopes of the Sierra Nevada (in California) to the ocean, and takes in the great transverse valley troughs or plains cradled between the Sierra foothills and the Coast Range, the great wheat granary of the Golden State, and also the fruit-growing section, yearly rising in importance.

In treating of these three divisions of the arid region more in detail they will be taken up in inverse order, beginning with the one named last in the above statement.

THE PACIFIC COAST DIVISION.

This division embraces the State of California, lying between the one hundred and twentieth degree of west longitude and the Pacific Ocean, east and west, and between the fortieth and thirty-first degrees of north latitude.

In the San Joaquin Valley, at Fresno, and at different points in Southern California, as Los Angeles, San Gabriel, Riverside, Anaheim, San Diego, water is found to be attainable at moderate depths, and apparently in all directions. This subterranean supply, wherever it has been reached and utilized, is greatly reducing the need of surface irrigation.

Fruit growers and wheat farmers in Southern California unite in the testimony that after irrigation has been practiced for some years a given supply of water suffices for a largely-increased area, the explanation being that when water is first applied to arid land a large part of it sinks deep into the dry earth, or is carried away laterally by seepage; whereas, when the lower strata, and, to some extent, the lands adjoining those under irrigation, are moistened, the amount of water absorbed in excess of the actual needs of vegetation becomes comparatively small. How much effect this increased humidity of the soil may have on the atmospheric humidity is not yet known, but the increase of evaporation due to this circumstance and to the cultivation of trees and plants must ultimately produce a beneficial change in this regard.

The full industrial use of water in California must necessarily be governed by the larger topographical and other physical conditions. The precipitation seldom exceeds 22 inches annually, and over a greater portion of the State falls below that figure. The wide range of variation in rainfall is illustrated by the following facts: At Fort Redding the range of three years was from 15.9 inches to 37.4 inches; at Sacramento the range of seventeen years was from 11.2 inches to 27.5 inches; at Millerton, six years, from 9.7 inches to 49.3 inches; at Stockton, three years, from 11.6 inches to 20.3 inches; at Fort Tejon, five years, 9.8 inches to 34.2 inches; at Monterey, five years, from 8.2 inches to 21.6 inches; at San Diego, twelve years, 6.9 inches to 13.4 inches; at Benicia, twelve years, 11.8 inches to 20 inches. The above figures show the rainfall for calendar years; the following show the amount of precipitation during the rainy season: Clear Lake, 1,300 feet elevation, six years, 16.2 inches to 66.7 inches; Visalia, three years, 6.7 inches to 10.3 inches; San Francisco, twenty-two years, 7 inches to 49.3 inches; Pillarcitos, nine years, 39 inches to 82 inches; Sacramento, twenty-four years, 4.7 inches to 36.4 inches; San Diego, twenty-two years, 4.5 inches to 14.8 inches.

The importance of California warrants a fuller description of the State, its topography, and other conditions bearing on the question of irrigation within its limits. There are two great mountain ranges running northwest and southeast, namely, the Sierra Nevada and the Coast Range. The former is from 4,000 to 8,000 feet high and the latter from 1,000 to 6,000 feet. The two ranges are connected in the southern part of the State at Tehachipi, and in the northern at Mount Shasta. The Sierra Nevada Range extends along the eastern border of the State and is about 450 miles long. The Coast Range extends along the coast to the northern and southern boundaries of the State. The base of the Sierra Nevada Range north of Fresno has an average width of about 80 miles. The Coast Range averages about 65 miles in width. Between the two ranges are the great Sacramento and San Joaquin Valleys, which together are about 450 miles long by 55 miles wide, and may be termed the heart of the State.

In the northern part of the State, and north of the junction of the two great mountain ranges, is the Klamath Basin, through which the Klamath River runs for a distance of 225 miles, between steep hills and mountains and rocky cañons, in a southwesterly course to the ocean. The whole basin of the Klamath is very rugged for a distance of 40 miles from the coast, and along the main river there is very little valley or bottom land. However, there are several small rich valleys and near the lakes there are large fertile tracts. Pine, cedar, and fir forests cover the mountains, and there are other valuable trees, both on the mountains and in the valleys. In the extreme southeastern portion of the State is the Colorado Desert, about 140 miles long by 70 miles wide, which is the dry bed of a former inland sea. Another great basin, called the Mojave Basin, lying north of the Colorado Desert, extends into the southern part of the State, the surface of which is cut up by many irregular ridges of mountains.

The Coast Range is composed of a multitude of ridges and is intersected by numerous long and narrow valleys of fertile soil, comprising those of the Los Angeles, Salinas, Santa Clara, Sonoma, Napa, and Russian Rivers. The State has numerous small rivers. In the central portion are the Sacramento and San Joaquin, each in its meanderings about 350 miles long. These are the only navigable streams in the State. From the Sierra Range westward into the Sacramento flow the Pitt, Feather, Yuba, American, Consumnes, and Mokelumne Rivers. Into the San Joaquin flow the Calaveras, Stanislaus, Tuolumne, Merced, Chonechilla, and Fresno. Into Tulare Lake flow the Kings, Kameah, Tule, and White Rivers, and into Kern Lake the Kern River. All of these are considerable streams, with an average length of about 120 miles. The upper half of each is in the steep and rugged mountains, where they are torrential in character. After reaching the plain their currents are gentle, and the banks low, fringed with oak, sycamore, cottonwood, and willow.

The rivers of the Coast Range flowing westward into the ocean south of San Francisco are the San Lorenzo, Pajaro, Salinas, Carmel, El Sur, and Cuyama, Santa Inez, Santa Maria, San Buenaventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, Santa Margarita, San Luis Rey, and San Diego. Many of these are constant streams to within 10 or 15 miles of their mouths, and all of them pass through rich valleys. North of San Francisco the streams of the Coast Range which empty into the ocean are the Russian, Eel, Elk, Mad, Klamath, and Smith Rivers, besides many others of less importance, all of which are permanent streams, bordered with narrow valleys at the foot of the mountains. To all of the rivers of the State flow many small tributaries. There are several important lakes, the Tulare, Owens, Kern, Clear, Klamath, Goose, Fall, Eagle, Honey, Elizabeth, Tahoe, Mono, and Dry Lakes. There are also a number of smaller ones.

The southern portion of the great interior basin of California is commonly known as the San Joaquin Valley, although it comprises the San Joaquin, Tulare, and Kern Valleys. The Tulare Valley is separated from the first named by a low ridge of land, scarcely noticeable, and in times of high water the southern lakes and rivers find an outlet through Fish and Fresno Sloughs into the San Joaquin River, thence to San Francisco Bay. Properly, there is no division lying between the San Joaquin and Sacramento Valleys. The greatest length of San Joaquin Valley is 260 miles, the width varying from 30 to 70 miles. The area is 11,290 square miles, or 7,225,600 acres. The eastern and western sides of the valley slope from the base of either range of mountains towards the lakes or streams in the lowest part, at the rate of 5 to 8 feet per mile; also northward to tide-water in San Francisco Bay, with a general fall of 1 foot to the mile.

The Mount Diablo or main Coast Range on the west side of the valley has an average height of about 1,700 feet. The Sierra Nevada Mountains on the eastern side of the valley rise to a much greater height. Mount Whitney, in Tulare County, has an altitude of 15,056 feet, and is the highest peak within the United States. From this mountain the summit-line of the range gradually lessens in height towards the north and more rapidly to the south. These mountains are rugged and broken, sharp, rocky ridges and granite spires rising abruptly to great altitudes. In the small valleys between these ridges is perpetual snow, and about the base of Mount Whitney are a number of small glaciers. This region has some of the wildest, grandest, and most beautiful scenery in the world. The San Emidio, or Tejon Mountains, a spur running at right angles to the Sierra and Coast Ranges, and joining the two, form the southern boundary of the San Joaquin Valley. The foot-hills commence in the northern part of Fresno County at an altitude of 300 feet above sea level, and in the extreme southern end of the valley at a height of 400 feet. In the hills are many valleys, some of them large and level, others more uneven.

In the Coast Range there are few valleys. About the base of the range are gently-sloping table-lands at an altitude of 100 to 250 feet above the valley, from which the mountains ascend to sharp and narrow ridges cut transversely at intervals of a few miles by natural passes extending through the range. The flanks of the Sierra broaden towards the south. The Sierra foot-hills in the portion of Tulare County, midway between the northern and southern boundaries, rise suddenly from the plain, but to the northward and southward, in Fresno and Kern Counties, the slope is more gradual, the hills lower, and the belt wider.

To the eye of the traveler the plain generally presents a very level surface. In Fresno County, on the eastern slope of the valley, are scattered hillocks 20 to 30 feet in height, with a wide base, rendering them inconspicuous even at a short distance. These are not observable elsewhere in the Southern San Joaquin Valley. Extending along the entire length of the eastern side of the valley, near the foot-hills, is a belt of uneven country known as "hog-wallow" land. These "hog wallows" are little mounds ranging from a few inches to 3 or 4 feet in height, averaging 1 to 2 feet, with a diameter of 16 to 50 feet. There are no deep river-beds traversing the upper part of the valley, although further north these are common. The beds of the southern streams, in fact, are in almost every case higher than the general level of the plain, having been built up into low, wide ridges, by the alluvium deposited during the rainy season through a long series of years.

Fresno, Tulare, and Kern Counties form the Southern San Joaquin Valley. The three counties have an aggregate area of 21,770 square miles, or about 13,932,800 acres. Of this large extent of country 13,885 square miles, or 8,886,400 acres are mountain and hill land; and 7,885 square miles, or 5,046,400 acres are in the valley, making a body of arable land in these three counties (deducting the surface covered with water) equal to some of the larger Eastern States. This land is divided among the counties as follows: Fresno, 4,480 square miles, or 2,867,200 acres of mountain and hill land, and 3,520 square miles, or 2,252,800 acres of valley land; Tulare, 3,835 square miles, or 2,454,400 acres of mountain and hill land, and 1,775 square miles, or 1,136,000 acres of valley land; Kern, 5,570 square miles, or 3,564,800 acres of mountain and hill land, and 2,590 square miles, or 1,657,600 acres of valley land, including the gently sloping plain skirting the base of the hills. There is a more gradual ascent from the valley proper in Kern than in either of the other two counties. The numerous valleys, large and small, in the mountains and foot-hills are not estimated as valley land.

There is a large portion of the Southern San Joaquin Valley that is not dependent upon the streams for irrigation, the necessary quantity of water being obtainable from artesian wells. The artesian belt extends from one end of the valley to the other. A good flow is usually obtained in boring to a depth of 300 to 600 feet. The first successful boring for artesian well water in Tulare County was made by the Southern Pacific Railroad in 1879 near Tipton, and a flow rising a half inch above the rim of the casing was secured at a depth of 310 feet. The well is on the eastern margin of the belt. This water was used for irrigating a 40-acre tract of forest trees, which it did successfully. No other wells were bored until 1881, when the Enterprise well, 4½ miles west of Tulare, was bored, and a flow of 1½ inches obtained at a depth of 330 feet.

No rock is encountered in boring, strata of sand, clay, and gravel, succeeding one another. It is therefore necessary to use iron casing the whole distance, which is forced down after the auger. The depth at which the first water-bearing stratum of sand or gravel is penetrated is from 310 to 640 feet, although some of the wells have been put down to a depth of 800 feet, passing through several of these strata. The deepest in Tulare County are in the northwestern part, near Lemoore. The section in which the greatest number of good, flowing wells have been obtained is west of the Tulare and near Tipton, the water from some of them rising to a height of 5 or 6 inches above the casing. Wells are also shallower here than about Lemoore. The average depth in Tulare County is about 450 feet. There are in Tulare County about two hundred wells. It is impossible to give the exact number, as so many new ones are being bored. Since the success of the Enterprise well the number has been increasing continuously and rapidly.

In Fresno County fewer wells have been bored. In the southern part of the county water is obtained in one well at a depth of 152 feet. Others have been bored in the region bordering on the San Joaquin River, the depth of these averaging from 150 to 200 feet. In Kern County, at the southern extremity of this great basin, artesian wells were bored several years ago and water was obtained at a depth of 200 to 250 feet, the average depth being less than in Tulare County. Some fifteen or twenty wells have been bored in the county. One, 470 feet deep, furnished about 30 gallons per minute. Others have been bored more recently north of Poso Creek, in the region about Delano and Alila, and elsewhere in the county. The average flow from the wells of Tulare County may be placed at 2½ inches above the casing.

The quantity of water furnished by a well of this capacity is about 247 gallons per minute, or a little more than half of a second foot. In parts of the San Joaquin Valley shallow wells have been known to fail after two or three successive years of light rainfall, and to flow again after a wet season. This has not happened in the southern portion of the valley. The deeper wells continue to flow regularly. It is claimed that some of the wells in Tulare County will each irrigate 160 acres of land thoroughly; and after the ground has been irrigated and cultivated a number of years, and the methods of applying the water perfected, a greater acreage can be successfully watered.

The Mussel Slough region in Tulare County was the first to be irrigated on a large scale, and soon became famous for the productiveness of its land. In the foot-hills there is generally sufficient rain, except in very dry years, to mature crops. Where the soil is loose and sandy, and where irrigation has been in use for a term of years, little water is required other than that supplied by the rainfall, the ground being sufficiently moist from seepage. In places moisture will permeate the ground for miles from the ditches. In some portions of Kern County the farms comprise from 640 to 1,800 acres, and the checks made for irrigating are surrounded by strong, low embankments, made with a view to permanency. The ditches are made on the highest land, and the levees inclosing these irregularly-shaped checks are built so as to take advantage of the natural inequalities in the surface.

The foot-hill region contiguous to the great valley which has been frequently referred to, deserves more extended notice. This belt is of varying width, extending along the Sierra Nevada Mountains. In the mild climate of the Southern Joaquin plain, it is most valuable for the growth of citrus and other semi-tropical fruits. It is particularly adapted to early fruits of all kinds. It has already been stated that fruit ripens much sooner in the orchards of the Fresno and Tulare County foot-hills than on the plains. The same is true of Kern County. Experience demonstrates that in the valley at the mouth of Kern River Cañon, twelve miles from the Southern Pacific Railroad at Sumner, frosts begin one month earlier than in the valley and cease a month earlier in the spring, and during the coldest period are less severe than on the plain.

Peaches in the foot-hills have ripened a month earlier than on Kern Island; all kinds of stone fruits mature early, while other kinds that do not bear well or regularly in the valley grow to perfection here. An isothermal line drawn through the axis of this belt would traverse the lower and more easily cultivated portion of the foot-hills and at the southern end of the valley would extend upward and inland to the abrupt mountain wall where Kern River Cañon bisects the range, where it would approach nearer to the valley than further north, owing to the topography of the mountains and not to other conditions influencing climate. Above the thermal belt, extending through the region of black oak to and into the pine and redwood forests, is an extensive area adapted to the production of a great variety of crops, and particularly to those fruits that require a cooler climate than that of the lower foot-hills and plain. The soil is rich, but the greater part of the hill land is covered with a dense growth of chamiso, manzanita, chaparral, and other brush, which must be cleared before the land can be cultivated.

Small clearings have already been made, and the result has been to encourage others to enter or purchase and do likewise. At no distant day this will be an important section of the agricultural and fruit-growing portion of the three counties named. It is a healthy region. The rainfall is greater than in the valley, and, by conducting water from the mountain streams, by the system of piping employed in other parts of the State, a sufficient supply can be obtained to irrigate all the best cultivable land; and by the conservation of water in reservoirs during the wet season the small streams could be depended upon to furnish a sufficient supply for a large aggregate area not readily reached by the main streams. Above an altitude of 1,200 feet in Fresno, 1,500 feet in Tulare, and 2,000 in Kern County, there is sufficient rainfall to make irrigation unnecessary.

In the region midway between the plain and the mountains proper the hills are generally precipitous, and although small valleys are numerous, there are few of any considerable area. Land in the Southern San Joaquin Valley remote from water supplies has in only a very few instances advanced materially above Government price; whereas that lying contiguous to or supplied with water has advanced several hundred per cent. in value, having been converted from grazing to productive agricultural and fruit land. In Fresno County only has the colony plan of settlement been carried to any great extent. At present there are two colonies in Tulare County, and one or two large tracts of land for sale in lots of 10 to 40 acres. Twenty acres are sufficient for fruit growing, and 40 acres is the largest tract that one man or family should attempt to cultivate, for it pays better to give careful attention to 20 or 40 acres than to imperfectly work more. The first colony started in Fresno County was the Central, near the town of Fresno, on the west side of the railroad. The land on which it was located was a treeless, uninviting plain, and, except in the wet season, verdureless. Now the elm, fig, cherry, and other trees give names to the avenues along which they are planted, and the tract presents a succession of flourishing orchards and vineyards, with scores of beautiful and comfortable homes, surrounded by shrubbery, green lawns, and flowers. Other colonies have since been started, and are in a more or less advanced state. The principal ones are the Washington, Nevada, Fresno, Scandinavian, Easterby, and American, which follow in the order named.

Land is still to be had with permanent water rights, the price depending on the conditions.

The area of California in its relations to irrigation falls into the following divisions:

(*a*) The natural area of sources, supply, and reservoirs; that is, the higher portions of the Sierra Nevada, upon the western flanks and summits of which the snow precipitation is heavy, whose physical formation creates the great catchment basins, and whose altitude is sufficient to break, deflect, and desiccate the great moisture-bearing currents from the Pacific Ocean.

(*b*) The foot-hills region, extending from Mount Shasta to the San Bernardino Range. This is the seat also of the important mining operations of the State. It is, consequently, the area in which the water-supply section has been largely drawn upon and made extensively available by means of catchment areas, dams, ditches, and flumes. It is also, especially in what is designated as the lower foot-hills where the altitude is below 2,500 feet, an area in which these supplies and distributing agencies, natural and artificial, have been extensively utilized for agricultural and horticultural purposes.

Experience has proved that in this subdivision of the State, which for all practical purposes embraces nearly all of Northern California, irrigation must, for such industrial purposes, be heavier and more continuous than elsewhere. Irrigation enterprises therein have up to date been largely of a personal and individual character, except where the hydraulic mining companies have utilized their larger water-works and channels, with the surplus waters they controlled, by selling the latter to the farmers and horticulturists of the region. The quite recent judicial decisions restraining the hydraulic miners from pouring their slickens or debris into the upper streams and rivers of the State, thus destroying the value of the agricultural regions below as well as filling up the navigable portions of the rivers and raising the beds of San Pablo and San Francisco bays, must have the effect of greatly enlarging the agricultural utilization of the catchment areas, reservoirs, and main ditches used heretofore almost exclusively in the mining industry.

(*c*) This subdivision embraces the great valley region of the State, its most important wheat and grain growing section, and includes the extensive drainage basins of the Sacramento, San Joaquin, Feather, Bear, Yuba, American, Cosumnes, Mokelumne, Tuolumne, Merced, Kings, Fresno, Kern, and other streams, large and small. It covers an area of over 34,000 square miles, divided into sixteen counties, within which every problem connected with the industrial use of water and its conservation, legal and practical, is in process of both application and discussion. The most extensive canal system, and the combination of farming interests in the control of supply, or the application of capitalistic enterprise to induce land settlement primarily and water purchase subsequently, are to be found therein.

There are also, as already noted, well-developed artesian belts in the upper portions of this region. The lower portions are subject to tidal overflow and river inundations, while the existence of water at a moderate depth is being demonstrated in almost every portion of the great valley areas. This region embraces not only the major portion of the wheat-producing area, but is also the seat of large viticultural and horticultural activity.

Perhaps the most gratifying as well as significant fact developed by the irrigation experience of California, especially in the valley region, is that connected with quality of the soils, which are generally of great thickness and tenacity. Underlying the surface soils there are found almost everywhere at moderate depths, impervious strata, by which the water drawn too rapidly from the overdrained surface has been happily preserved. Owing to this almost generally established condition of things, water throughout the central portions of the State is being obtained from ordinary wells. It is pumped to the surface and distributed by the agency of the peculiar wind-mills in use, which are now known in all parts of the world.

The altitude of the California valleys is nowhere very great, and the lower portions are at but moderate heights above sea level. That of the foot-hills region is from 2,500 to 4,000 feet. California experience brings into prominence the question whether the cultivation of the soil in surface-dry and wind-desiccated areas, such as the valleys and lower table-lands of that State were assumed to be but a few years since, does not of itself tend directly to an increase of surface humidity by capillary attraction, or the drawing upon the water supplies that are unquestionably found in the underlying strata. Another question suggested is, whether such supplies are not to be found flowing below or underlying considerable areas of the valley plains and table-land regions of Central and Southern California and elsewhere within our dry areas. The precipitation of rain and snow, with the annual melting of the latter, would be in itself sufficient to feed such subterranean bodies.

It is evident that these aqueous supplies do not directly flow to the ocean within the hydrological channels and basins that have been worn through the surface and other strata. The streams and rivers of California do not carry volume enough to account for the amount of deposition that must occur within the subdivision designated as the source and supply area of the Sierras. If subterranean bodies of water exist they will be utilized by borings. The high altitude at which waters disappear into the earth must give them, when arrested under the table-lands and plains below by impervious strata, a force ample to propel the same up and above the surface, and to give them the value of living perennial streams or springs. In fine, there are two sources of subterranean waters to be utilized in California for fuller industrial purposes. The first is the water arrested in its flow from the surface, at moderate depths, and which can be reached and drawn upward by the loosening of the soil consequent upon cultivation, and by the hardy and penetrative qualities of the plant roots. The other source is to be found in the deeper bodies that are presumably the lost and sunken floods of the Sierras. That such bodies exist there is more than mere conjectural data to indicate.

(*d*) Passing from these points, the other division of Southern California embraces some of the features of both the valley and foot-hills regions. It is also affected in its western portion by the trade winds and other coast influences, and its extreme southern and eastern section is modified and molded by the great Colorado plateau formation, of which the boundary mountains and mesas, or table-lands, are in fact a part. There are great stretches of arid mesa, or secondary table-land, which must be counted as desert, though the major portion has native grasses sufficient to feed a large number of animals. There is also sufficient development, especially in Los Angeles and San Bernardino Counties, to indicate the possibility of profitable reclamation in the case of considerable portions of these so-called deserts, provided the waters now available, explored, and in part utilized, can be distributed over their surface. The Southern California division approaches, in many of its products, a semi-tropical fertility and luxuriance. It is the chief seat of the orange culture. The lemon, olive, date, fig, almond, pomegranate, nectarine, and other fruit trees requiring warm and fecund soils, grow in abundance there. The upper or northerly part of this subdivision forms a part of the great wheat-producing area of the State.

The table-land or mesa portions are also extensively utilized for the pasturage of cattle and sheep. In the southern section of California, the absence of any considerable hydrological basins with flowing waters in them makes the methods of conservation of great significance. The economic use of water therein has almost approached perfection. The conservation of the Los Angeles River, and of other similar but smaller streams, within the three great counties into which Southern California is legally divided, is in proof of this.

The practical legal issues involved in the conservation and distribution of water for economic uses within the State of California are of a most serious character.

There are district community methods of control, as seen in the laws and policy found operative within the State. The first comes from the admixture of the Indian community, or pueblo life, with that of the Spanish conqueror, both being affected and shaped by the needs and customs of people to whom irrigation has always been a prime necessity. The Indian, with his tribal, clan, or village organization, has regarded land and water as common or communal property, in the use of which all had a right. The Spaniard regarded the land as his by conquest, but held that the water, being necesssary for its full utilization and profit, must be controlled by the king, *i. e.*, the state, and therefore should be for the public use. The English common-law doctrine of riparian rights had no place in the economy of either people. The public charge of the water-supply at Los Angeles and elsewhere in Southern California illustrates the perfection to which the community may bring control and distribution. The discovery of gold brought with it in California the rapid adoption of a miners' code, both as to the occupation of mineral "claims" and the control of water rights.

This code has become the foundation of nearly all our legislation, State and national, as to the disposition and use of the mineral lands, and, in a minor degree, it has also dominated and shaped the water usages so far as mining is concerned. The public use of water is fairly established in that connection; but as to the other and larger utilization of water in agriculture, the drift of events within the dry area, but especially in California, seems to have been in the opposite direction. This tendency began early in the construction of large works in the upper foot-hills and Sierra regions, for the purpose of obtaining a water-supply large enough to carry on the great hydraulic enterprises, which for a quarter of century past, have been so marked a feature of California gold-mining.

The water-courses and supplies of the State have thus been passing under the control, in forms more or less direct, of incorporated companies. Some of these are composed of those by whom both land and water are to be used in conjunction. Others are composed of those who have obtained possession and ownership of great bodies of land, and, in order to either use or dispose of them, have been obliged at large outlays to bring water thereon. The tendency in all directions is to put the farmer at the disposal of chartered collectors of water taxes, for such must be the form of payment for the use of one of the great divisions or elements of natural property—water. This tax must be equitable or otherwise, according to the character of the State or local control over those who vend the same, and the needs thereof by those who pay. What will be the effect on this tendency of the recent decision of the State Supreme Court upholding the doctrine of riparian rights, as against the rights of appropriation, remains to be seen. The different systems have ample illustration within the State, that of community control being seen in its most marked aspects at Los Angeles, while different methods of association and incorporation and of construction and control of irrigation works will be found in large form at such points as Riverside or Fresno, in Tulare and Kern Counties, and elsewhere.

The State has, by legislation and administrative control, done something these later years to put private enterprise, in its dealings with the water-supply, under the sovereignty of the body politic. California is now divided into irrigation districts. A State engineer has been placed in a supervisory position over these, and encouragement is given to the owners, occupants, and cultivators of land to enter upon the work of irrigation in the form of joint-stock associations. Under these laws the extent of conservation and distribution is in a large degree placed under control, and local rules, sanctioned by experience, are allowed to have the force of law.

The State Supreme Court has recently complicated the question of water use by the decision above referred to. The particular case that called this decision forth relates to a great irrigation enterprise carried out by large land owners, who have diverted a considerable portion of the waters of the Kern River, in Southern California, over the lands they own, and are preparing for sale and occupation. The land owners on the same stream below the ones adversely affected by the decision have gained their points, but the questions involved in the decision are so serious as to affect the rights and necessities of many thousands of farmers and horticulturists all over the State, and may, indirectly, perhaps, do so over the entire area within which the artificial conservation and distribution of water must become a prime necessity of land occupation and cultivation.

It is suggested by some intelligent irrigationists that it would be easy for a wealthy corporation of water holders and land owners to cripple all the farmers below them on any stream unless there was some modifying legal right enforced, either by priority of ditch construction or water preemption, or by the enforcement of the common-law doctrine of riparian rights, modified as to the amount to be used by any owner, and providing for the return of surplus or unused waters to the upper streams, so that land owners below may have their equities preserved.

There is another and very important question to be considered, and that is as to the effect of irrigation on the general health. In California considerable attention has been paid to this subject, and in 1884 a report on the subject was made by the State Board of Health. There are conflicting opinions in the report made by the board. In certain counties, as Ventura, Santa Barbara, San Bernardino, San Diego, irrigation has been employed for over a century, and the absence of malarial disease is noted, as well where irrigation is practiced as where it is not.

Other portions of California show a marked increase of malarial fever where irrigation is practiced. It is not difficult to discover the reasons for this. In Los Angeles and other valleys in extreme Southern California, where the soil is, as a rule, sandy or gravelly loam of unknown depth, the water used in irrigating sinks into the ground or (on sloping surface) drains off immediately. It does not remain to saturate the soil unless there be a stratum of clay (hardpan) near the surface. In such sections of the country there is almost entire freedom from malarial diseases. Along the bottom lands of rivers, and where the slope is insufficient to insure good drainage, or where the soil is saturated constantly, the case is different, and there are intermittent and remittent fevers during the warmer seasons of the year. The fact that the people living in these low, wet sections of country are dependent upon impure or surface water for drinking and domestic purposes aggravates the difficulty, for it has been demonstrated that people living in a fever-and-ague country are tolerably exempt from the disease if they drink only pure water.

In the report of the State Board of Health of California we find a report made by W. S. Green, editor of the Colusa Sun, to the State Irrigation Convention, in May, 1884, in which the above theory is fully sustained by observation. He says:

> My conclusions are, therefore, that irrigation will tend to bring on malarial disorders as it raises the water in wells to a newer strata of earth, but no farther. When we irrigate so as to produce this effect we must go down after pure drinking water or bring it to our houses by pipes.

The methods employed to prevent zymotic diseases in irrigated districts is receiving considerable attention, and the most successful is the removal of the surface water, and, where possible, provision for systematic drainage; for, says the report, "irrigation, in order to be innocuous, must go hand in hand with drainage."

From all portions of California letters from medical practitioners and other residents are in singular accord in saying that irrigation, when properly managed, does not produce any increase of malarial diseases.

THE INTRA-MOUNTAIN DIVISION.

Within the limits of the second great division of the arid region extending east and west from the one hundred and fifth to the one hundred and twentieth degree of west longitude, and north and south from the British to the Mexican boundary, irrigation works and experiments of value will be found in progress, small in extent, perhaps, in most cases, but extensive when aggregated.

The larger portion of Colorado, New Mexico, Wyoming, and all but a small portion of Eastern Montana, are within the limits assigned. The whole of Nevada, Utah, Idaho, and Arizona, and the eastern half of Oregon and Washington Territory are also included. The region comprises 15 degrees of longitude and nearly 17 of latitude, and makes a total area of 1,100 by 900 miles square. In its northern portion very little worth mentioning has been attempted in the way of irrigation. In Utah, however, an extensive system is well under way, and a large area has been reclaimed. The value of the work accomplished is seen not only in the valleys near to Salt Lake City, but in all the Mormon settlements within the Territory. The influence of the Mormon polity in directing industrial activity has often been commented upon. In no one thing is it more apparent than in this great work of the conservation and distribution of the water supply. It exhibits several noteworthy features. They are:

(*a*) The treatment of natural water supplies, under legislation, as public property, to be used for the common benefit.

(*b*) The construction of all distributive agencies (artificial) at the cost necessarily of those to be benefited.

(*c*) The incorporation of the expected beneficiaries by neighborhood companies, under general law, and the assessing of costs co-operatively, by means of share purchasing and holding, according to the number of acres to be served by the water so utilized.

(*d*) The distribution of water under stated regulations, which have the effect of law, under the supervision of an officer specially chosen for the purpose.

(*e*) The payment for this authorized use by means of stated rates, levied upon the volume of water used.

That these deductions are well founded will be seen from the following facts and statements, which are given at some length because of the importance and adaptability of the Mormon method:

The usual plan of irrigation is to go well up the cañons and start a channel 20 feet wide by 4 feet deep, and carry this along the side of the cañon, and then round the side of the main range so as to command as large an area of level land as possible. The ditching, except in the rocky portions at the head of the cañon channel, is done by plow and scoop, one of the lightest of the latter implements, worked by a pair of mules, being invariably used. There are two 30-mile-long main ditches led along each side of the Jordan, and one 35 miles long is conducted from a mountain cañon in the direction of Provo, along the foot of the range towards Salt Lake City, thus providing water for a considerable area of country under the ditch.

The Mormon irrigation law provides for the proclamation as a water district of any piece of territory which can be commanded by an irrigating ditch, the nomination of water masters, penalties against wasting water, the giving of permission to carry the ditch through any private property upon a fair valuation for the land used, authority to tax for maintenance of channels, and to appoint taxation trustees, whose powers are made very broad with respect to determining what shall be described as land benefited by the construction of the irrigating channels. The law also gives protection to primary water rights, which means that any person who has drawn water from a water-course by means of an irrigating work previous to the proclamation of any locality as a water district, has his right protected as a primary claim up to the quantity of water he was in the actual use of at the date of proclamation. Having covered these points, the law has made the way open for the action of private enterprise, which in all cases undertakes the construction. The next step is the formation of a joint-stock company, which may be formed of not less than three individuals and not more than seven, and further provides that such corporation work shall be exempted from general tax for county and State purposes, to which all other kinds of property are subject. The farmers and others interested then meet in public and arrange the formation of the company and the distribution of shares, and then vote as to whether the tax for maintenance and management purposes, after the main ditch has been completed, shall be upon all the land within the water district or upon "the land to be benefited." They can also confer arbitrary powers upon the assessing trustees, as a difficulty had been found to occur with parties who refused to contribute to the maintenance tax on the plea that they are not taking water, although, owing to favorable positions in relation to either the main or subsidiary ditches, their lands are being effectually irrigated by means of seepage. The shares are always $10 each, and each share represents an acre of land with a perpetual water right to that acre, subject only to the maintenance tax. The company being formed, the farmers, or intending farmers in most cases—for many of the tillers have just arrived as immigrants—of the water districts take up all the shares they can. This is usually a very small percentage of the whole, as they are poor, and their shares are mainly paid for by work in the ditch. After the farmers have taken their shares, the wealthy citizens take the balance amongst themselves, and on goes the making of the ditch, the intending farmers working on their farms at the rate of $20 a month, and the non-working shareholders putting on labor by contract, which amounts to an average of 10 cents per cubic ard, the heavier work in the cañon being by special agreement, acording to the difficulties of the work. When the work is completed he farmers have as many water rights as they have taken out shares, nd they who have furnished most of the capital then begin to make heir profit.

The most expensive thing in connection with an irrigating work in Jtah, as elsewhere, is the main head, where the water is taken from he stream. Sometimes the channel is taken sufficiently far up the añon to tap the stream without a dam, but in other cases it is found he lesser of two expensive works to dam the stream at a lower point ather than undertake the heavy quarrying or tunneling required higher ip. The dams are of various kinds, according to circumstances, but hat known to engineers as "the mud-sill" is mostly built over broad, hallow streams, and "the crib," used for deeper and narrower torrents ip the cañons.

Small farmers generally secure a water right for each acre, but others vho hold, say from 40 to 80 acres, sometimes only take water right suficient for half their area, working one-half as a tillage-farm and the ther as a grazing block, alternately. A water right means the privlege of taking as much water as the land requires during the irrigating eason, and the maintenance tax varies from 10 cents to 16 cents per cre per annum, according to "easiness" or otherwise of the channels. Subsidiary ditches, called laterals, are made by the farmers at their wn cost, from side heads fitted with sluices, through which the waternaster lets out as much water as may be required during any particular lay. Thus there may be ten farmers along a certain lateral holding rom five to forty acres of land each, and they may have water rights to over the whole or any part of their holdings. The water-master knows ow many water rights are along each lateral, and every morning he looks t his notice boxes, which are attached to the sluice-heads at the place vhere the laterals leave the main channel. The farmers generally arange to irrigate day about, each at the proper time posting up the otice, "I intend to irrigate to-day," and as the water-master knows how nany acres are possessed by the persons signing, and how many water ights, he is able to make his arrangements accordingly. His water gauge, which is simply a wooden slat in the lateral sluice-head, graduted so as to let a crtain number of cubic feet run through in a given ime, is then lifted to the necessary mark, and the water laid on until he irrigation is completed. The gauge is arranged so as to let a cubic oot per second flow through for each hundred acres of land. Thus: f A's notice represents five water rights, B's fifteen, and C's thirty, he water-master knows that fifty water rights want water, and he sets he gauge to run at the rate of half a cubic foot per second. This is ot for the purpose of measuring the water, but only as a gauge to arange the flow to suit the irrigation requirements of the several farmers ituated along the lateral.

The time occupied in flooding a certain area differs according to the 'lay" and quality of the soil. The water-master soon learns how much ime each irrigator usually occupies, and his knowledge on that oint, together with the law against wasting water, which is strict, perates to prevent the flow of water longer than is absolutely required. 'he water-master notes in his book the time of letting the water on, ogether with the number of water rights that are drawing, and it is his usiness to visit the irrigators about the proper time, and see about hutting off.

Each acre of land brought within the influence of the canal is increased in value, and the ten-dollar shares go up in the market. The water enables the working farmer to pay his passage-money back to the Mormon Church, together with the tithe of all he raises, and, further, the expenses of his maintenance, advanced to him during the construction of the ditches; and yet after paying all these charges, in addition to say 10 cents an acre for maintenance of the ditches, he makes money. Each share in the Provo ditch, for instance, costs $10. That represents an acre of land, with a perpetual water right. Without the water right the land was absolutely valueless. It is now quoted at from $25 to $60 per acre, according to situation.

The extent of irrigation in the settements of Utah cannot be accurately stated, as there have been no general official statistics published since 1875. At that date there were in the twenty organized counties 2,095¼ miles of principal canals, costing $1,918,174, and 4,888¾ miles of tributary canals, costing $503,320. This was a total construction of 6,984 miles of canals and ditches, at a cost of $2,421,494. The total cultivated area within the district "under water" was 302,766 acres, of which 106,184 acres did not require the application of water at all. Mr. Caine, Delegate in Congress from Utah, under date of December, 1884, estimated that there were in the four most prosperous counties of that Territory irrigation (main) canals, as follows:

Counties.	Main canals.	Estimated cost.
	Miles.	
Weber	165	$300,000
Utah	150	250,000
Cache	175	550,000
Salt Lake	190	1,250,000
Total estimate	680	2,350,000

As compared with 1875 the increase in tributary canals in the counties named is 2,132 miles, costing $216,596. The cultivated area "under water," or within the irrigation districts of these counties, in 1875, was about 102,000 acres, or one-third of the total. It has unquestionably doubled, as the estimated increase of main canals in 1884 over 1875 was 289 miles, or very nearly one-half more than the main mileage of 1875.

It would not be fair, Mr. Caine suggests, to consider the increase as great in other counties of the Territory. But there has been no retrogression. An estimate which adds one-fourth to the system of irrigation and the acreage affected by it in 1884 would be within moderate bounds for the remaining sixteen counties. That would give a total cultivated area of over 656,000 acres, a main canal construction of 2,810 miles, and one of tributary works aggregating 7,750 miles.

Mr. Caine sends the following interesting report on water supply and irrigation in Utah:

> Whatever conditions future developments may bring about, the present water supply in Utah Territory is surface. It depends entirely upon the fall of snow in the winter, and to a slight degree upon the rainfall during the fall and spring months. As a natural consequence the character of the water supply is found in mountain streams. The fall of snow in the mountains is incomparably greater than in the valleys, and it lasts much longer, for the reason that the cold is much severer.
>
> The snow packs in the ravines until almost as hard and solid as stones. The solidifying is materially assisted by what are termed "January thaws," the result of a marked relaxation in the severity of the weather, which generally occurs during

the month of January. This temporary relaxation is invariably followed by a renewal of the rigor of winter, when the snow that has settled and become packed by the thaw, freezes until it is almost a solid mass of ice. This snow is the source of all streams in Utah save the little running water that comes through rains.

The volume of these streams depends entirely upon the season of the year. During the winter months the supply is very small, for the reason that the quantity of snow is at its minimum and the cold has a tendency to stay the flow. With the disappearance of winter and the increased warmth of the sun the snow begins to melt, the volume of water increases and continues to grow until tiny and puny streams are swollen into rushing torrents, sometimes causing great damage from the oveflowing of their banks. The water supply attains its maximum height between the 10th and 20th of the month of June. This statement may be given the force that attaches to a rule almost if not entirely without exception. The solidifying and freezing of the snow in winter, as above stated, makes certain the tenure of the water supply that would otherwise be both uncertain and disastrous; it prevents the too rapid melting which would result in absolutely uncontrollable torrents for a period, and thus makes the streams available for agricultural purposes.

A few artesian or so-called artesian wells exist, but their depth, according to the ideas of those most conversant with the subject, is not great enough to entitle them to be classed among wells that tap living streams of water. The outflow is comparatively small, and some fill up after a few months and cease to flow. The average depth is not to exceed 200 feet, and they are believed to be fed only by seepage from the mountains, or catch-water seeking for a subterranean outlet or inlet. The seepage out from Great Salt Lake it is also thought may contribute toward the maintenance of the so-called artesian wells in Salt Lake Valley, and these wells exist almost exclusively in this valley. There are few living springs, none of such importance as to make any figure in the estimate of the water supply of the Territory. Indeed, the combined supply from this source is insignificant.

There is a notable exception to the general proposition laid down above, as regards the source and supply of water. This exception is found in the southern portion of Utah, that part lying to the south of the Great Basin. This country is between 2,300 and 2,600 feet above the sea-level; as a consequence there is little if any snow-fall. The winter is a rainy season. The country is terribly broken, sand and sandstone being the prevailing groundwork. If snow does fall it remains a few hours at most and then disappears. Rain-storms of any magnitude invariably produce swollen streams, and the torrents pour down the narrow rugged beds and begin to disappear almost as soon as the rain ceases. Hence the volume of water is precarious, uncertain, and generally insufficient. It is greatest in the spring of the year, and sudden thaws in distant mountains to the north are generally accompanied by loss of property, as the sandy, unstable character of the soil renders it an easy subject for the action of water, and dams, canals, and large tracts of farming lands are sometimes swept away.

The experience of Utah farmers as to the best methods for increasing and preserving the water supply would be valuable only to people surrounded by a similar country with like elemental conditions existing. The only means of increasing the water supply is, so far as existing knowledge throws any light upon the subject, confined to the introduction of genuine artesian wells. Experiments, sufficiently thorough to clearly demonstrate the success that would attend the digging or boring of such wells in Utah, have not been made. The best opinions, however, are that the geological conditions existing in Utah are peculiarly favorable to their introduction and successful development.

The Territory, or rather its habitable portion, is composed of valleys, mountains, and cañons, with some lakes. The melting snow on mountain and in valley which fails to find its way into some of the streams must sink and collect somewhere, and there is a well-founded belief, which could easily be verified, that beneath these valleys are subterranean lakes that would feed with a never-failing supply of water innumerable artesian wells. To increase the supply by other means would be to increase the fall of snow, a thing humanity is not yet prepared to base a calculation upon. Preserving methods are, however, more practicable, and nature has done her best to make that task as light as possible. The outlet for all streams is into the valleys. The streams come from the cañons high above the valleys and the supply can be preserved or saved by the construction of reservoirs or by dams. In case the latter method was adopted it would simply be necessary to select the most suitable place in season and place a dam across the ravine.

The work would be more or less expensive as the stream was large or small and the cañon wide or narrow, but in every cañon suitable points abound, and as the future development and continued prosperity of Utah largely depend upon her permanent and increased water-supply, her people will be forced to resort to damming the streams within their natural confines in the ravines. To what extent this idea, carried out, would save the water that yearly runs to waste, the word "waste" being used here with the knowledge that every drop of water is invaluable in a country where agriculture depends upon irrigation, it is absolutely impossible to form even an estimate, and for several reasons: First, the volume of the stream differs every day in the year, and one year from another. Second, it would require a measurement of the streams and a knowledge of the amount consumed in irrigation and in local evaporation, which would increase with increased distributing canals and ditches. It may be safe to state, however, that if complete and thorough methods of saving were introduced, all the land in the Territory, if it could be reached, could be well and thoroughly irrigated; this, too, without resorting to artesian wells, so vast is the amount of water that runs to waste during the winter, spring, and early summer months.

There is in Utah no bureau of statistics, and it is impossible to give any correct idea of the extent, character, and cost of the artificial means introduced in the Territory for the utilization and distribution of the water supply. As to flumes for mining and railroad purposes it is impossible to give even an estimate. Very little is necessary for railroad purposes, and where water is not otherwise naturally available, wells are utilized, and form the almost exclusive supply. It is sufficient with regard to mining, as flumes are used in this case to carry off water from the lower workings of the mines. There is no hydraulic mining carried on in Utah, for which reason supply flumes, save for reduction works, concentrators, leaching purposes, and milling, are unnecessary. It is not infrequently the case that the water out of the mine is more than enough to run the mills.

The Ontario mine, in Summit County, has run a tunnel flume underneath the ground for a distance of more than a mile. This flume carries off the water from the workings of the mine 600 or 700 feet deep, and saves the expense of hoisting a large volume of water to the surface. With this exception it is probable that the men most interested in the mines do not themselves know the cost of their waste or surplus water flumes.

In 1875 the legislature of the Territory authorized and provided for the compilation and publication of general statistics with regard to the material, educational, and social status of the Territory. The work was done probably as well as circumstances rendered possible at that time, the task never having been previously attempted. Since that time no further attempt has been made looking to the gathering of statistical data; that is, no attempt of an authorized character beyond what was accomplished through the Census Bureau in 1880. These reports were doubtless approximately correct when made, but material alterations would be necessary at this date, and they can only be guessed at now, save in the cases of Salt Lake, Cache, Utah, and Weber Counties, where something like reliable data have been secured.*

With the increase in main canals there has been a proportionate increase in subcanals, or distributing canals, and irrigation ditches in the same ratio as the irrigating ditches hold to the main canals, as seen in the accompanying Exhibit A. It would be a mistake to suppose that there has been an increase in the other counties proportionate with that of the four specially referred to above; the four named are the most populous, fertile, and wealthy in the Territory, and their facilities for increased water supply are incomparably greater than those found in other portions of the Territory.

As heretofore stated, the increase and decrease in the water supply depends entirely upon the fall of snow in winter, and, to an unimportant degree, upon the fall of rain in the fall, spring, and early summer months. A very noteworthy fact, attested on the best of authority, is that for a period of years there has been a steady increase in the water supply. It has been thought by many that the claim of increased water has been more imaginary than real. The claim, however, has been verified by measurements made in Great Salt Lake, which is the reservoir for many of the largest mountain streams, including the Jordan, which is the outlet for Utah Lake, the Bear River, the Ogden, Weber, Logan, and Blacksmith Fork, and innumerable smaller streams.

The lake has a shore line of 350 miles, and since 1856 the water has increased 14 feet in depth; and Great Salt Lake, depending as it does entirely upon the inflowing of mountain streams and that amount of water which is not consumed by agricultural utilization, shows beyond question that there has been a marked increase in the water supply.

This rise in the body of the water of the lake has taken place, it must be remembered, during a period when there was a rapid increase in the demand for water for agricultural purposes.

The increase in the water supply in Utah since its settlement by Mormon pioneers in 1847 has been not less than 75 per cent., and might be honestly put at 100 per cent.

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* These have been presented in tabular form above.

Whatever changes may have taken place in the grasses in Utah are artificial. The native mountain "bunch grass" has become so well known for its remarkably nutritious character that rather than change it the desire of the people of Utah, or those owning stock, would be to propagate it.

Where irrigation has been applied for a few years there has been a perceptible decrease in the amount of water necessary to properly irrigate the land. The decrease is placed at about 25 per cent. The census returns give the most available information as to the extent of irrigable lands.

The value of such land depends entirely on its location, not only in a territory but in a precinct or county, and upon the character of the soil, which often differs materially from land adjoining it and enjoying the same water advantages. In earlier days all persons interested in the digging of a canal would turn out and keep on working under the direction of a person chosen by themselves. Later laws were passed on the subject, and will be found by reference to the statutes of the Territory, which will give the fullest attainable information as to water rights and conditions in the Territory.

Grants, of course, are given to municipal and canal corporations, counties, and districts, but these also are set forth in the statutes.

The most important undertaking of the class under consideration yet accomplished in the Territory was the construction of a canal to supply Salt Lake City with water. The city was bonded for the purpose, and the canal was commenced in December of 1879 and finished in the fall of 1881.

Its length is something over 20 miles, and its source is the Jordan River, a short distance below the point where Utah Lake has its outlet into the Jordan. The canal is 20 feet wide at the bottom, the depth being 6 feet, sufficient to carry 4 feet of water.

The city was authorized to borrow $250,000 on its bonds for the construction of the canal. The expenditures in detail were: For excavation, $130,832.77; for dams, flumes, bridges, and culverts, $39,636.17; for lumber for flumes in the city—the distance being 1½ miles of redwood flumes—$24,844.56; for right of way, $39,253.97; for recording deeds, &c., $456.25; for engineering, $10,282.80; for incidental expenses, $2,446.13; and for puddling, &c., $6,757.65. In cities the municipal corporations control the waters, water-masters being appointed to regulate the division of the water.

In seasons when there is a scarcity of water after the irrigating period has commenced nearly every drop of water is consumed, and irrigating goes on night and day, according to the hours in which the streams are allotted to different persons. The waste referred to above is scarcely known during the irrigating season; it is during the winter, before and after the season for watering. It will be proper to state here in explanation of a foregoing statement, that some of the higher valleys to be made desirable for agricultural purposes must resort to artificial means, such as artesian wells, as the streams flowing into them are insufficient to meet wants that will arise, while their altitude is such that other streams cannot be forced into them.

(For regulation of water rights, see Utah statutes of 1880, page 36; for acts relating to Salt Lake City Canal, see same, page 55 and page 85; for law relating to irrigating companies, see Utah statutes of 1884, page 127.)

The records taken at Fort Douglas, a short distance outside Salt Lake City, for twenty years, show a mean temperature of 52 degrees and an average precipitation of 17.68 inches. The first half of the period, that is, from 1863 to 1872, the mean is placed at 18.81; while from 1873 to 1882, inclusive, it is stated at over 16.65. It is noticeable throughout the entire mountain area that wherever the records have been kept long enough (at some army posts this has been the case) for comparison the latest years will show a marked diminution of the precipitation, while equally as marked is the increased humidity of the soil where settlement has, by irrigation, been enabled to cultivate the same. The decrease in atmospheric humidity is believed to proceed from the destruction of the timber on the sides of the ranges, and from the elevated foot-hills, valleys, and cañons thereof. The observed increase in terrene humidity is a factor of great importance.

Turning southward, Arizona is found to be making considerable progress. The southern, or Gila Valley portion of the Territory, and its smaller central valleys, offer a considerable area for the farmer when irrigation is applied. The difficulties of the problem are found not only in the newness of the region, as to settlement, but in the want of system and the confusion of ideas as to the lawful use and control of water.

The Mormon system would probably bring about in both Arizona and New Mexico the same admirable results that it has secured in Utah. It is estimated that there are in the Territory about 2,800,000 acres of land of the best quality, with surface water sufficient to irrigate the same by a reasonable expenditure on ditches. Of the above area not quite 300,000 acres are in cultivation. There are at least 10,000,000 acres of rich land that could be reclaimed by means of artesian and other wells, if they can be obtained.

For convenience of arrangement in considering its agricultural capabilities, Arizona may be divided into: (1) The Colorado Valley; (2) the valley of the Gila and those of its tributaries, including the Salt River as far north as the thirty-fifth parallel; (3) the Santa Cruz Valley, the isolated locations of Pinal and Pima Counties, and the vicinity of the New Mexico line; (4) the Colorado Chiquito Valley; (5) the southwestern portion of Yavapai County, surrounding Prescott, and the valley of the Rio Verde, with its tributaries.

In one of Lieutenant Wheeler's reports of exploration in Arizona, California, and Nevada, a comparison is made between the capabilities of certain portions of the Territory and those States, which brings to light some important facts. The Arizona portion compared is bounded in longitude by the meridians of 111 degrees and 113 degrees 45 minutes, and in latitude by the parallels of 34 degrees and 35 degrees 40 minutes, which include the southwestern portion of Yavapai County and a small strip of Mohave County, by no means the best agricultural region of the Territory, and scarcely up to the average. This is compared with the eastern portion of Southern California, and the southern portion of Nevada, in the same latitude:

	California and Nevada.	Arizona.
	Per cent.	*Per cent.*
Agricultural, irrigable, and arable land	2	25
Timber	6	10
Grazing	88	30
Barren	4	35

In the Colorado Valley the soil is rich in the chemical combinations requisite for fertility, and only in small patches contains too large a proportion of clay. In some places it has also small amounts of chloride of sodium and sulphate of lime. The fertilizing reddish mud resembles that of the Rio Grande and of the Nile, and its quantity varies from 0.1 to 0.5 per cent. (1–1000 to 1–200) of the water, which is good to drink even when considerably colored by the mud. As compared with the above-named rivers, it contains less potassa, more phosphoric acid, and much more carbonate of lime, the presence of the latter valuable ingredient being due to the immense limestone beds through which the river flows in the upper part of its course.

The following table (mud from the Colorado having been collected) exhibits a comparative analysis of the mud of these rivers:

	Colorado.	Rio Grande.	Nile.
Hygroscopic water	3.27	1.890	....
Chemically bound water, soluble in hydrochloric acid	1.14	3.122	....
Potash	0.103	0.284	0.166
Soda, with trace of lithia	0.074	0.064	0.022
Lime	....	1.479	1.725
Carbonate of lime	12.50	5.190	....
Magnesia	0.69	0.080	0.046
Oxide of iron	....	3.640	8.804
Alumina	2.26	1.308	
Phosphoric acid	0.146	0.092	0.143
Sulphuric acid	Trace.	Trace.	Trace.
Oxide of manganese	Trace.	....	....
Insoluble in hydrochloric acid	78.1	82.55	....

As to the extent to which the Colorado River could be rendered available for irrigation, it has been appropriately remarked by geologists that the country bordering on the Colorado is the most conspicuous example in the world of over-drainage; for nowhere else do we find a stream that for hundreds of miles cuts its way 500 to 600 feet deep through solid rock. The Colorado, supplied by streams from the mountains, where rain and snow are abundant, cuts its way through a rainless and therefore desert region, in which the only changes are those resulting from the direct action of the atmosphere, so that no appreciable débris of any kind is furnished to fill up the excavations continued through millions of years, and only limited by an approximation of the level of the river bed to that of the waters of the Gulf of California. Lieutenant Wheeler estimates the area of land drained by the Colorado River and its tributaries to aggregate 242,065 square miles, mostly still owned by the Government.

The Salt River Valley is 25 miles in length by about 14 in width. With its estimated quarter of a million acres of rich, alluvial soil, capable of producing 25 to 50 bushels of grain to the acre, it ought easily to support 50,000 inhabitants, if there were a sufficiency of irrigating ditches and artesian wells to fully utilize its natural capabilities.

Near Phœnix an old canal, 8 miles in length by 20 feet in width, has been discovered, which has recently been cleared out and utilized. The remains of this and many others, together with numerous mounds whose surfaces are covered with fragments of pottery, prove that a race skilled in husbandry, irrigation, and manufactures many years ago appreciated the fertility of this valley, but left behind them no other records than their work.

The valley of the Gila, though cultivated along most of its course, is not available for semi-tropical productions in its upper part on account of October frosts. The White Mountain Indian Reservation (San Carlos) interferes with a continuous white settlement above Florence, as the lands of the Pimas and Maricopas do below it. These latter Indians have cultivated wheat, corn, pumpkins, melons, &c., for centuries, and have always been self-supporting, as well as the Papagoes, farther south, who, however, depend principally on stock.

From Yuma eastward the valley is extremely fertile.

At Oatman's Flat a large area is now being reclaimed.

The Gila bottom merges imperceptibly into the foot-hills, and has an average breadth of from 5 to 10 miles. Its soil is principally alluvial, and will produce two crops yearly. Irrigation is easily effected. The river averages 600 feet in width, and is 3 to 5 feet in depth when there is no rainfall and no water from the mountains. The banks along the whole of this tract are so low and sloping as to afford unusual facilities for the construction of ditches. Excellent crops of wheat, barley, and vegetables are grown. In the vicinity of Florence is an extensive tract of rich bottom and second-mesa or table-land, on which are now grown the cereals, alfalfa, the sugar cane, and vegetables and fruits generally, including orange and lemon trees. Fruit culture in the Gila Valley is extensive. Cottonwood, ash, and locust are abundant. Further up the valley the Pueblo Viejo has, with its tributary valley of Ash Creek and others, at least 100,000 acres of good farming land.

On the uplands and farther up the valley itself, near the line of New Mexico, the daily variations in temperature are much less and the frosts begin later. Still further up its course, within the borders of New Mexico, the Gila River has upon its margins much good agricultural land. The bottom lands generally are quite rich in potassa and phosphoric acid.

The valley of the Francisco River, a tributary of the Gila, near the line of New Mexico, is good for grazing and timber, and has in general a rich soil. The San Pedro River is a tributary of the Gila, its mouth being between Florence and San Carlos, and its source in the Huachuca Mountains, near the Mexican line. There is good land, good timber, and excellent range for stock. Considerable valley land is now under cultivation, and irrigation is generally required.

The Santa Cruz Valley, though smaller in extent, is equally productive in proportion to its area. It is more compact, and all of it is adapted to semi-tropical fruits, as well as to the vegetables of the temperate zone.

According to information received, about 250 miles of main canals have been completed during the past two years, or are under rapid construction. With the tributary feeders and laterals Southern and Central Arizona now has completed, or very nearly so at least, about 700 miles of irrigation works. As this Territory has always been considered one of the most unpromising in the dry and mountain regions of this country, these facts are of a cheering character. The most astonishing reports are made of the fertility of the areas "under water."

The physical configuration of Arizona shows it to be, as already stated, an over-drained region. This is in itself sufficient to account for the unquestioned aridity of a large portion of the Territory, but settlement and time are proving there, as well as elsewhere within our mountain area, that the supplies of water, with proper conservation and distribution, will be found more important and available than has generally been considered at all probable. In the narrow and precipitous valleys of Central Arizona there are natural reservoirs, of which, with comparatively little outlay, valuable storage basins may be created and force obtained to raise the water high enough for reaching extensive portions of the mesa or table-lands adjoining the river valleys. Several of the minor streams are known to sink, and their recovery and use for industrial purposes will be found a task not difficult to engineering skill.

In the southeastern portion of this Territory there are extensive grassy plains or broad intervals known as "cienegas," on account of the nearness of water to the surface. The cattlemen have taken advantage of this fact. It would seem to argue the existence of subterranean waters. There are two rainy seasons, in the winter and summer months, respectively. In the summer the rains are often violent and torrential in character, disappearing almost as suddenly as they come. In April and May there are often neighborhood showers, seeming to be limited in area, as if the currents in their passage from the Southern Pacific, coming through the Gulf of California, were broken by the higher peaks and whirled in circular eddies over the sections visited. They are known by the Mexicans and Indians as "shepherd rains." No artesian wells have yet been sunk, but at several points the Southern Pacific Railroad has obtained water at comparatively moderate depths. The following tabular statements, forwarded by the railroad administration, are a valuable presentation of the results of these endeavors:

Wells on Gila, Tucson, Rio Grande, and El Paso divisions of the Southern Pacific Railroad of Arizona, Southern Pacific Railroad of New Mexico, and Galveston, Harrisburg and San Antonio Railway.

Stations.	Distance from Yuma.	Elevation above sea-level.	Strata.		Description.	Remarks.
			Depth.	Material.		
	Miles.	*Feet.*	*Feet.*			
Sentinel	89.6	688	20	Clay	300 feet 8-inch pipe, 500 feet 7-inch pipe, inside 8-inch; 1,000 feet 5-inch pipe, inside 7-inch; total depth, 1,029 feet; first water shut off; second water risen to within 185 feet of surface.	Supply good; quantity fair for all purposes; well finished November, 1882.
			80	Lava		
			250	Sand (water)		
			256	Sand		
			400	Clay		
			129	Sand and gravel (water good).		
Gila Bend	119.2	737	34	Sand and clay	All 7-inch casing; total depth, 260 feet; 122 feet to surface of water.	Water inferior quality for steam purposes; well finished November, 1881.
			128	Cement		
			16	Gravel		
			69	Red clay		
			13	Fine gravel (water)		
Mario Spa	156.3	1,186	25	Sediment soil	Dug well 8 feet square; total depth, 50 feet; 41 feet to surface of water.	Incrustation avoided by frequent "blowing off;" well finished April, 1879.
			15	Cement		
			10	Gravel (water)		
Second well 3 miles east of station.			16	Sediment soil	Dug well 10 feet square; total depth, 30 feet; 23 feet to surface of water.	Good supply, of good quality.
			5	Cement		
			9	Gravel (water)		
Casa Grande	182.3	1,396	3	Soil	Dug well 6 feet square; total depth, 50 feet; 41 feet to surface of water.	Supply and quality good; well finished May, 1879.
			10	Clay		
			4	Sand		
			20	Cement		
			2	Sand		
			3	Cement		
			2	Gravel		
Picacho	201	1,610	23	Soil, sand, and clay	Dug well 4 by 6 feet; total depth, 120 feet; 115 feet to surface of water.	Fair supply of good quality; not used for locomotives.
			72	Cement		
			20	Coarse gravel		
Red Rock	214.9	1,865	50	Soil	Bored well 6 inches in diameter; total depth, 270 feet; 218 feet to surface of water. New well dug January, 1883, 8 feet square, 176 feet deep, 173 feet to water.	Strong supply of excellent quality; well finished January, 1883.
			70	Cement		
			61	Coarse gravel		
			87	Clay		
			50	Soil		
			67	Cement		
			58	Cobble-stone		
Separ	426.7	4,523	2	Soil	8-inch bored well, 534 feet in depth, 300 feet to surface of water.	Fair supply of good quality; well finished June 7, 1881.
			43	Clay		
			23	Sand		
			240	Cemented gravel		
			220	Clay		

Gage	447.1	4,488	240	Red clay	8-inch bored well, 343 feet in depth, 226 feet to surface of water.	Fair supply of good quality; well finished September 15, 1881.
			10	Fire clay		
			93	Clay and gravel		
Deming (on main line)	466.0	4,334	4	Soil	Dug well, 4 feet square, 60 feet in depth, 54 feet to surface of water.	Supply and quality excellent; well finished January 11, 1881.
			23	Sand		
			13	Yellow clay		
			9	Sand		
			6	Gravel (water)		
Deming round house				Same material as above	Dug well, 6 feet square, 63 feet in depth, 55 feet to surface of water.	Supply and quality excellent; finished November, 1881.
Zuni	477.6	4,187	4	Soil	Dug well, 6 feet square, 56 feet in depth, 48 feet to surface of water.	Fair supply, of inferior quality.
			21	Sand		
			18	Clay		
			12	Sand		
			2	Gravel (water)		
Cambray	492.6	4,224	155	Clay and gravel (water)	7-inch bored well, 273 feet in depth, 155 feet to surface of water.	Supply and quality good; well finished August 8, 1881.
			30	Red clay		
			20	Black clay		
			15	Brown clay		
			24	Clay and gravel (water)		
			20	Red clay		
			9	Black rock		
Lanark	527.8	4,165	365	Sand	6-inch bored well, 400 feet in depth, 358 feet to surface of water.	Fair supply of good quality; well finished November 15, 1881.
			30	Red clay		
			15	Cement		
			38	Sand		
Lordsburg	407.0	4,245	80	Cement and gravel into bed rock, 40 feet.	Old dug well, 4 feet square, 120 feet deep. Bored in bottom of chamber to depth of 400 feet, 10-inch casing reduced to 7-inch. Now dug well, 8 feet square, now being dug.	Some water developed, but not enough for a locomotive water-station; work suspended March 1, 1881.
			88	Cement and gravel into bed-rock.		
Marfa	194.9	4,692	170	Sand	10-inch bored well, 1,200 feet in depth, 252 feet to surface of water, 10-inch casing reduced to 7-inch.	Well finished July 15, 1883.
			10	Clay		
			150	Quicksand		
			182	Red rock		
			343	Shale		
			35	Red sand rock		
			70	Shale and gravel		
			10	Concrete		
			20	Shale		
			52	Shale and gravel		
			38	Shale		
			10	Sand and gravel		
			110	Sand rock		
Rillito	230.4	2,058	25	Soil, sand, and clay	Dug well 4 by 6 feet; total depth, 120 feet; 115 feet to surface of water.	Quantity and quality good; well finished March, 1880.
			70	Cement		
			25	Gravel to clay		
Tucson	247.5	2,390	50	Cement and gravel	Dug well 8 feet square with four drifts; 44 feet to surface of water.	Supply and quality fair; well finished November, 1881.
Paniano	275.6	2,536	6	Soil	Dug well 6 feet square; total depth, 17 feet; 9 feet to surface of water.	Supply good; quality for steam purposes inferior; finished May, 1880.
			8	Clay		
			3	Gravel		

Wells on Gila, Tucson, Rio Grande, and El Paso divisions of the Southern Pacific Railroad of Arizona, &c.—Continued.

Stations.	Distance from Yuma.	Elevation above sea-level.	Strata.		Description.	Remarks.
			Depth.	Material.		
	Miles.	*Feet.*	*Feet.*			
Benson	293.5	3,578	100	Dug	Old well abandoned	No water; good supply from San Pedro River.
			300	Bored		
Cachise	322.6	4,222	3	Soil	Dug well 4 by 5 feet; total depth, 50 feet; 44 feet to surface of water.	Not a locomotive water station.
			8	Clay		
			8	Clay and sand		
			31	Cement		
			2	Gravel		
Wilcox	333.4	4,104	5	Sand	Dug well 5 feet square, 15 feet in depth; 7 feet to surface of water.	Supply and quality good; well finished January, 1881.
			3	Adobe		
			2	Sand		
			3	Red rock		
			2	Gravel		
Bowie	357.1	3,759	280	Sand (water)	Dug 150 feet, 6 square; bored 150 feet, 7 inches in diameter; 118 feet to surface of water.	Fair supply of good quality; well finished December, 1880.
			14	Red clay (overlying water).		
			6	Gravel (supply doubled)		
San Simon	372.8	3,609	3	Soil	Dug well 5 feet square, 75 feet in depth; 70 feet to surface of water.	Fair quality, good supply; well finished May, 1881.
			7	Sand		
			30	Clay		
			15	Gravel and sand		
			8	Clay		
			6	Gravel (water)		
Playas Valley	393	4,150	2	Adobe	Dug well 6 feet square, 73 feet in depth; 58 feet to surface of water.	Fair supply of poor quality.
			6	Sand		
			41	Clay		
			12	Sand		
			7	Sand and clay		
			5	Gravel (water)		
Deep Well			1	Adobe	8-inch bored well, 1,008 feet in depth; 37 feet to surface of water.	Alkali water in first and second strata of sand; work suspended May 26, 1881.
			9	Sand		
			26	Clay		
			1	Sand (water)		
			15	Clay		
			19	Sand		
			548	Blue clay		
			200	Lime rock		
			15	Red shale		
			65	Blue clay and lime rock		
			168	Red rock		

Sanderson	314. 2	2, 774	50	Clay and gravel	10-inch bored well, 987 feet in depth, 487 feet to surface of water, 10-inch casing reduced to 6 inch.	For forty-eight hours the pump gave undiminished flow of 900 gallons of water per hour; supply good; well finished June 13, 1883.
			100	Clay		
			77	Clay and gravel		
			28	Limestone		
			20	Red clay		
			8	Limestone		
			52	Sand rock		
			30	Blue clay		
			7	Sandstone		
			28	Hard rock		
			5	Lime rock		
			23	Flint rock		
			10	Shale		
			44	Sandstone		
			18	Quartz		
			300	Lime rock		
			30	Shale		
			35	Lime rock		
			122	Sand rock		
Dryden	335. 2	2, 109	200	Limestone	10-inch bored well, 1,706 feet in depth, 491 feet to surface of water, 6-inch casing in bottom of well.	Pump gave 1,800 gallons of water per hour, with undiminished flow for forty-seven hours.
			30	Sandy clay		
			450	Lime rock		
			10	Flint rock		
			80	Lime rock		
			15	Sandstone		
			25	Lime rock		
			30	Blue shale		
			160	Sand rock		
			20	Lime rock		
			30	Sand rock		
			5	Lime rock		
			25	Sand rock		
			15	Blue slate		
			125	Lime rock		
			20	Porous brown-stone		
			140	Limestone		
			135	Sandstone		
			77	Limestone		
			10	Sand rock		
			33	Lime rock		
			5	Sandstone		
			156	Limestone		
Lozier	358. 2	1, 535	423	Rock	9-inch bored well, 692 feet in depth, 200 feet to surface of water.	Shows flow of 500 gallons per hour after being pumped down to 180 feet.
			21	Limestone		
			248	Sand rock		

The annual precipitation of Arizona, as reported from five stations of the United States Signal Service, over an average observation period of six years, ranges from 2.04 inches at Yuma, on the Colorado, at an altitude of 200 feet above the sea level, to 15.76 at Fort Grant, an altitude of about 2,500 feet. The mean average for the Territory during the six years ending June, 1883, will be only 9.34. The following table, compiled from the volume of 1881 (Schott's) in the Smithsonian "Contributions to Knowledge," and also from the Signal Service reports, for the dates given, will illustrate these deductions:

No. 1.—*Smithsonian reports.*

Stations.	Period of observations.	Extent.		Latitude.		Longitude.		Altitude.	Annual mean.
		Yrs.	*M.*	°	′	°	′		
Camp Bowie	August, 1867, to December, 1874	6	8	32	10	109	50	4,872	15.28
Camp Grant	September, 1866, to December, 1874	6	10	32	54	109	51	2,000	15.68
Camp McDowell	do	8	2	32	13	110	53	....	11.45
Camp Verde	December, 1868, to December, 1874	6	1	34	34	111	34	3,160	10.85
Fort Whipple (near Prescott).	June, 1865, to October, 1874	7	5	34	33	112	27	5,318	19.28
Camp Lowell (near Tucson).	May, 1867, to December, 1874	4	11	32	13	110	53	2,000	30.41
Camp Crittenden	April, 1868, to November, 1871	3	7	31	43	110	35	....	17.89
Camp Goodwin*	January, 1866, to May, 1870	3	11	32	52	109	51	2,816	26.58

* Near San Carlos.

No. 2.—*Reports from Signal Service stations.*

Stations.	Period of observations.	Extent.	Annual mean.
		Years.	
Camp Thomas*	September, 1872, to January, 1883	2	10.04
Camp Verde	November, 1874, to January, 1883	5	10.89
Fort Apache	October, 1877, to January, 1883	1	12.78
Fort Grant	November, 1875, to January, 1883	5	15.76
Prescott	November, 1873, to January, 1883	6	14.24
San Carlos	June, 1881, to January, 1883	1	15.37
Phœnix	May, 1877, to January, 1883	5	7.32
Tucson	December, 1878, to January, 1883	7	12.23
Yuma	November, 1878, to January, 1883	7	2.04

* About 50 miles from San Carlos and south on same range.

Ex-Governor Tritle, of Arizona, has written to the Department as follows in relation to the progress of irrigation works:

> Very little land reclaimed by artesian process; some little in Sulphur Spring Valley. It is very important that the attention of Congress should be invited to the value of development of water by artesian process in Arizona. Upon this point memorials have been forwarded to Washington from the Territorial legislature, and I have treated the subject at considerable length in my annual reports to the Secretary of the Interior for the years 1883 and 1884. At least 500,000 acres may be reclaimed. The principal canals and ditches are in Salt River Valley, Gila Valley, valley of Little Colorado, Verdé and Hassayampa Valleys, and the San Pedro Valley. Their extent and cost are not precisely known—probably 250 miles and $600,000.

The following is a list of water companies in Maricopa, the leading agricultural county in this Territory:

Post-office, Phœnix, Maricopa County: Arizona Canal Company, Grand Canal Company, Maricopa Canal Company, Salt River Valley Canal Company, Farmers' Canal Company, Griffin Canal Company, Dutch Canal Company, Montezuma Canal Company, San Francisco Canal Company.

Post-office, Tempe, Maricopa County: Tempe Canal Company, Mesa City Canal Company, Utah Canal Company.

The Gila Bend Canal Company, post-office Gila Bend, Maricopa County, is now engaged in constructing a large canal at that point.

Another enterprise is the Buckeye Canal Company, Phœnix, Maricopa County. Mr. Patrick Hamilton, commissioner of immigration, has written from Prescott that—

> There is no law, local or Territorial, regulating the control and distribution of water from the streams of Arizona for irrigating or mining purposes.

He adds the following memorandum:

> *Pinal County:* There are several canals in the valley of the Gila, near Florence, the largest being the Tiena Amerillo Canal Company. *Cochise County:* Only a limited area is cultivated in Cochise County. *Apache County:* There are several Mormon colonies established on the Little Colorado, Apache County. They irrigate successfully. *Yuma County:* A large water-way is being excavated at Texas Hill, in this county. *Pima County:* Irrigation in this county is mainly to the valley of the Santa Cruz, near Tucson.

The northwestern part of the intramontane region or division embraces the State of Nevada and the eastern half of the State of Oregon and of the Territory of Washington. The western line of these portions of Oregon and Washington will be the one hundred and twentieth degree, as far south as the northern line of California. The summit of the Sierras Nevada is the western limit of Nevada. Within this region, mainly mountain and plateau, or basin, the indigenous grasses afford nutriment to large herds of cattle. Some irrigation enterprises are already under way; others are projected. The Columbia River and its affluents make an extensive basin, wherein concurrent testimony establishes the existence of an available water supply, large as to extent and volume. In illustration of this, there is a project now under way for utilizing the waters of the Snake River, the largest affluent of the Columbia, and turning them by means of irrigation canals, &c., over the Snake River plateau, a great area, embracing 12,000,000 acres, now almost rainless. The project is a possibility, and indicates the attention that is being directed to these matters. There is reason to believe that a sufficient and available body of water exists in natural ways and channels combined with the average precipitation and the storage of the snowfall in the higher cañons and channels of the Sierras to provide for the reclamation of a considerable portion of eastern Oregon and Washington Territory, while the present rapid increase of pastoral use establishes the superior grazing value of the indicated region. The timber area, according to the Federal census of 1880, will not exceed 4 per cent. of the whole, but that may be fairly set down as an underestimate, owing mainly to the insufficient data upon which it is based.

The opening of the Northern Pacific Railroad, since 1880, has shown that this calculation falls short of the facts. A large increase of land occupation and population has already followed railroad construction.

The State of Nevada presents the most forbidding aspect, so far as the water problem is concerned. The average precipitation will range therein at about 12 inches per annum, falling a little below at points most exposed or distant from the hydrological system of the Columbia, and rising to about 22 inches where under its direct influence. Nearly the entire area of the State is within the basin region. Its average altitude is about 5,000 feet.

The Carson and Humboldt Rivers form the only hydrological areas of any importance. The drainage basins of the Sierras afford valuable opportunities for water storage, natural and artificial, for Nevada as well as California. Lakes Tahoe and Pyramid are examples. The southern extremity of this portion is of an arid character. Yet there are some evidences of agricultural reclamation. In the Carson Valley there is some systematic effort at irrigation. The surveyor-general of the State reported in 1883 that within the counties named as the western half of the State there were twelve mining ditches with a total length of 31 miles; in 1884 the length, as shown by the report of the same officer for that year, had increased to 34 miles.

The irrigation ditches in 1883 were 518 in number; in 1884 there were 570; their length in 1883 was 1,040 miles, and in 1884 it was 1,091 miles. The area under water in 1883 was 77,910 acres; in 1884 it was 81,910 acres. These figures do not cover the full consumption of water, industrially considered, within the area of this State. There are small irrigation enterprises not fully reported, and in some localities wells and springs are utilized. Water for mining purposes is also brought by flumes and ditches, sometimes for long distances, and, for limited areas, incidentally serves agricultural uses. It is also shown, especially in Humboldt County, and elsewhere in the northern portion of the State, that water is obtained by wells sunk to moderate depths. The surveyor-general claimed that there are evidences seen of a climatic change in the direction of increased humidity. He says:

> Thunder showers are quite frequent in the early summer months, producing a freshness as exhilirating as it is enjoyable. These showers of late years have increased in frequency, and the rains of California seem to spill over the Sierras more often in winter than in the past.
>
> The last winter there was more rain than snow, and grasses this year, as a consequence, are more thrifty.

And he adds:

> If this change of climate keeps on in the same ratio, it will not be long that irrigation will be absolutely necessary.

Observations and records of an exact character have not been made for sufficient periods to lend more than an indicative authority to such statements. The following table is compiled from the Smithsonian records (Schott, 1881):

Place of observation.	Latitude.		Longitude.		Period covered by observations.		Dates of observations.	Average annual precipitation.
	°	′	°	′	*Yrs.*	*Ms.*		*Inches.*
Fort Halleck	40	49	115	20	5	8	November, 1867, to December, 1874.	10.96
Camp McDermit	41	58	117	40	6	4	February, 1886, to December, 1874	8.53
Camp McGarry	41	40	119	00	2	0	November, 1865, to October, 1868	22.46
Camp Scott	41	34	117	30	2	8	January, 1867, to April, 1870	17.33
Fort Churchill	39	17	119	19	3	9	January, 1862, to May, 1869	7.43
Fort Ruby	40	04	115	31	2	0	January, 1863, to October, 1868	15.61
Average for the State.								13.74

Taking the two longest periods of observation, those at Halleck's and McDermit, one on the extreme northern line and the other 2 degrees further east and one further south, we have an average period of observation of six years and one month, and an annual average precipitation of 9.75 inches. Camps Scott and McGarry, being only 2 degrees of longitude apart and practically in the same latitude, show during a briefer period, yet covered also by the longer range given for the other posts, a much heavier precipitation. The average of period is two years and four months, and the annual precipitation ranges from 22.46

down to 17.33, or an average of 19.9. At Fort Ruby, 1 degree further south and 2 degrees further east, the annual rainfall for two years is stated at 15.61. It is probable that this comparatively (for that region) large rainfall is due to some marked topographical features, which bring to bear the influences of the Columbia Valley system and perhaps of the "Chinook" or warm winds that blow from the "Kuro-Siwo," or Japanese current, and most favorably affect the climate and humidity of some portions of our intra-mountain region. The natural meadows of Nevada are largely found in the region indicated, and that fact also tends to indicate reasons for the greater precipitation shown by the Smithsonian tables.

The records of the Smithsonian and of the United States Signal Service observers, as well as observations taken by railroad employés and at the military posts of the United States, irregular though they are, run back for an average of twelve years. They indicate the annual precipitation of Nevada to be, in the northern portion, about 12 inches; in the central, along the line of the railroad and below, not over 9, under favorable circumstances; and in the southern it will run down to 6 or 7 inches per annum. Nevada is therefore to be regarded as the most unpromising portion on the whole of our dry area. Yet there is evidence that even there water can be conserved and made largely to aid the work of land reclamation. As a grazing State Nevada is steadily coming into prominence. The mildness of its winters, comparatively speaking, invites occupation for cattle and sheep. It has usually been found that pastoral occupation is accompanied, after a short period, by a marked increase in agricultural utilization.

That portion of New Mexico which lies west of the one hundred and fifth meridian embraces two-thirds of the Territory, and also its most important agricultural region. The principal centers of irrigation enterprise are in the Rio Grande and Mimbres Valleys. The former bisects the Territory almost from north to south. Irrigation therein and in the smaller valleys has been practiced by the Indian town-dwellers from a period long ante-dating the Spanish occupation in the middle of the sixteenth century. Water has been conveyed on the same land for centuries by ditch and by hand, and the soil remains as fertile as when first turned by the hand of man.

No entire or quite reliable statistics are available as to the extent and importance of the irrigation works within the Territory, but, as the population in 1880 numbered 119,565 souls, and at the present writing is estimated to be at least 140,000, raising within the Territory a considerable proportion of the breadstuffs they use, besides fruit, cattle, sheep, &c., it follows that the means of water distribution must be quite extensive. The number of farms is not less than 5,500; the yield is large, and the products of a varied character. The entire length of the irrigation canals and ditches will probably equal that of Utah. The Indian and Mexican laws and customs as to community uses of water still continue. They were preserved to those inhabitants by treaty when Mexico ceded to the United States a large portion of its northern territory. The average annual precipitation ranges from 12 to 16 inches, according to the altitude and locality.

Within that part of Colorado which lies west of the one hundred and fifth meridian may be found a large proportion of the irrigated districts, but the southern portion of the State contains the oldest farming section. A portion of it was formally under Mexican rule, and has the same agricultural and grazing characteristics as other portions of the Rio Grande Valley region. The water system of the State is considered to be the best yet devised in its supervision of outflow and distribution, and its method of settling and adjudicating disputes.

The possession of water under law can be obtained by companies or by neighborhood organizations for the purpose of distributing the same at certain rates, which are to be judicially decided upon if disputed by the users and purchasers. The ownership of distributing and construction works is in the hands generally of large and wealthy joint stock associations. The older water companies were formed by and from the agricultural colonies, which began, over twenty-four years since, the work of systematic land reclamation. The later constructions, those now operative and those in progress, are usually owned by great land companies. These works are planned on a large scale. The results are surprising, and will be more so in the near future, as a larger area is placed under water. The State is now divided into twenty-six water districts, in each of which a water commissioner has been appointed, to whom all questions of distribution are referred, with the right of appeal to the State district courts. A State engineer's office has also been created, to which all the engineering and other technical supervision belongs.

Such a thing as a drought is not dreaded by the agriculturist of Colorado. The cultivation of the soil is subject to a condition different from those which prevail in the East. Irrigation, although a necessity, bears with it some of the greatest blessings. There can be no irrigation except where water can be drawn from streams, and the area of arable land is small compared with the total area of the State. There are two river systems to the east of the mountains, that of the Platte, with its north and south forks, and that of the Arkansas. In the southern part of the State is the Rio Grande. On the western slope there are the Gunnison and the Grand, with their tributaries; the White River and the Yampa in the northwest, and the Rio Dolores, the San Miguel, and tributaries of the San Juan in the southwest. Only a small part of the land upon the plains can be supplied with water from the South Platte and the Arkansas. Farmng is confined to the valleys of the streams, while the intermediate country between the rivers is suitable only for grazing, owing to lack of water.

Prior to 1870 farming was confined to the immediate and narrow valleys of the streams. In that year the Union Colony was formed, and settled in the valley of the Cache la Poudre. From that settlement the town of Greeley has grown, becoming the center of one of the best agricultural districts in the State. The colonists constructed a large ditch, by which the water taken from the Cache la Poudre was conveyed to the upland country. From 1870 to 1874 many colonies were formed, and an irrigating ditch was constructed by each settlement. Within the last four years large corporations have constructed irrigating canals, relying for their remuneration on the receipts from the sale of water.

Immense canals have utilized a large portion of the water in the northern part of the State, and brought under cultivation tracts of land which were barren. Little has yet been accomplished in the valley of the Arkansas, although corporations have been formed for the construction of canals in the valley between Pueblo and the Kansas River. In the great San Luis Valley or Park there are canals aggregating about 150 miles in length, and capable of irrigating about 475,000 acres of land. The Grand Valley, in Mesa County, at the junction of the Grand and Gunnison Rivers, in the western part of the State, is one of the most fertile agricultural regions in the West. It has several irrigating canals, the largest one being that named the Grand Valley Ditch. Its waters serve 65,000 acres of land.

In Montrose and Delta Counties there is the Uncompahgre Valley, watered by a ditch covering 75,000 acres of land, supplied from the Uncompahgre River. The aggregate length of the irrigating canals in this State is estimated to be between 900 and 1,000 miles, and the land susceptible of being irrigated 1,700,000 acres. This does not express the limit of the arable land in the State, for that has not been reached. Mr. Nettleton, the State engineer, has ascertained by actual measurement, that the water supply of the Cache la Poudre is used over again; that is, the larger part of the water used for irrigating the land finds its way back to the stream in the form of springs and rivulets. A large quantity of water can be saved in reservoirs, and State Engineer Nettleton believes that the most suitable place for the construction of small reservoirs is in the foot-hills. Large ones capable of storing vast quantities of water could be constructed high up in the mountains, but would have to await the action of the Government, as the undertaking would be too vast for private enterprise.

Mr. Nettleton concludes that upon an average in Colorado a cubic foot of water per second will irrigate about 55 acres. In California and New Mexico the check system is used in applying water. The land is divided by ridges into squares, and the water allowed to run on a given square until it is covered, then a little channel is cut through the ridge to the adjoining square. This system requires extra labor, but is economical.

The cost of water in Colorado is now from $1.50 to $3 per acre per annum.

The soil of Colorado is exceedingly fertile, and the product very large. Wheat sometimes yields 40 or 50 bushels per acre, and is of an exceptionally fine quality. The average crop of potatoes is 150 bushels per acre. Vegetables grow to an enormous size, and are of a superior quality. Fruit raising has not developed as rapidly as the culture of crops, but what promises to be the paradise of that industry is the Grand Valley, in Western Colorado.

One of the most profitable crops which can be grown is alfalfa, three or four crops of which can be cut each season from the same ground, the aggregate yield being from 4 to 6 tons per acre.

Prior to 1860 the practice of irrigation in Colorado was confined to a few scattered Mexican settlements in the southern part of the Territory, with an imitation, but little improved, by the few American settlers in other parts of the Territory on the bottom lands lying immediately alongside the streams. The ditches were small and short, each ditch being constructed by the water user to suit his own requirements. The irrigation was consequently confined to small patches of ground scattered along the sides of the streams as the valleys would permit. The agricultural settlements were in the valleys. The uplands, locally known as "mesa," or table-lands, were not at that time thought to be capable of production, even if water were put upon them, and were considered fit only for grazing of cattle and sheep. The land taken up by the only American agricultural settlers was "first bottom," and a farm of 160 acres of cultivated land was thought to be immense. Gradual improvements were made during the next ten years, but were confined to bottom lands, irrigated by individual ditches.

Mr. Greeley, in his tour through Colorado in 1859, was impressed with the belief that the higher lands were best adapted for cultivation, if they could be irrigated, and on his return to New York had many conversations on the subject with Mr. Meeker, then agricultural editor of the Tribune. These conferences resulted in the formation of a colony which in 1870 settled in the valley of the Cache la Poudre, and the name of Greeley was given to the new settlement. In that year work was begun on the first canal for the conveyance of water to the table-lands then constituting the so-called "Great American Desert." The success achieved was due to the combined efforts of a community. Large blocks of land were brought into cultivation, and the example thus set led to the adoption of the present system of large canals, laid out by professional engineers to cover the highlands, which needed only water under the control of the irrigator to produce great crops.

Since that period the construction of irrigating canals has progressed under the protection of the laws of the Territory and State, until in some districts the appropriation of water has reached the limit of supply. From 1878 to the present time corporations and associations of individuals have undertaken the building of canals, each watering thousands of acres. They have brought into the State large amounts of capital and have revolutionized the modes of settlement. These canal schemes are analagous to the development of the present railroad system. Roads were formerly built to accommodate settlements already in existence; now they are built into the wilderness, inviting immigration and offering facilities that will in the future reimburse them. The irrigating schemes of Colorado are on the same plan. Surveys are made of lands available for irrigation and a plan conceived as an entirety. The work is done at a minimum of cost, and when the land is ready for cultivation settlers are invited. No trustworthy data can be given of the area of irrigated land in Colorado. An estimate based on the returns of the county assessors of the area of farm lands in the State gives, in 1883, 3,265,218 acres, and in 1884, 3,834,619 acres; assuming that three-tenths of this is irrigated land, the area of this land would be 979,565 acres in 1883 and 1,150,386 acres in 1884. The average yield of crops in 1885, where agriculture is exclusively carried on by irrigation, is estimated as follows: Wheat, per acre, 27 bushels; barley, 33; oats, 55; poatoes, 150 to 200; onions, 250.

The elevation of the farming lands of the State ranges from 3,500 feet, in the extreme eastern portion, to 7,500 feet in the upper valleys of the Rio Grande. The bulk of the land at present cultivated lies near the foot-hills on the eastern slope of the main divide, at an average altitude of about 5,000 feet. On the eastern slope of the mountains, and comprising about one-half of the total area of the State, lies the region known as the "plains," or, as once called, the "Great American Desert." It was only desert while destitute of water, the soil being generally productive when irrigated. The amount of land capable of cultivation is only limited by the water supply which can be brought onto it from the mountain streams which, flowing eastwardly, combine and form the South Platte and Arkansas Rivers. The South Platte passes out of the State at its southeast corner and the Arkansas at latitude 38° north. After leaving the mountains these streams receive numerous tributaries on both banks, but these are all of one character, deep floods after heavy rainfalls, quickly subsiding to muddy streams during the wet season, and drying up entirely for three-fourths of the year. No irrigation is possible from the waters of these creeks unless artificial reservoirs are constructed to impound the flood waters. All the supply for direct irrigation from the main rivers must be derived from the mountain tributaries, which last longest and give the most reliable supply only when they head on the high ranges of perpetual snow.

The divide between the Arkansas and South Platte Rivers is known in the State as the Colorado Divide, and the summit between the two valleys is from 1,000 to 2,000 feet higher than the rivers, the distance between them varying from 120 to 210 miles. All the water available for irrigation, even if the flood waters were all impounded, is only sufficient to cultivate a fraction of this area, and the great bulk of cultivation will be concentrated on the most available lands nearest the foot-hills extending eastwardly along the streams as far as the water supply will extend.

In the valley of the Rio Grande the irrigated lands lie in and around the San Luis Park, and in the narrow tributary valleys, more especially the Saguache, and the upper valley of the main river. On the western slope the situation is the reverse of that on the eastern slope, there being an excess of water and but little irrigable land. Of course there are local exceptions on both slopes. The amount of irrigable land in Colorado is limited by the supply of water, and this supply can only be determined by a complete system of gauging of all streams, and estimating the extent and storage capacity of reservoirs for impounding the surplus flood and winter waters of all streams available for irrigation. It is generally conceded that the rainfall and humidity of the States west of and contiguous to the Mississippi has increased with the settlement and operations of husbandry, but all attempts have failed to show, *by record*, that a similar increase has occurred with the settlement of the States and Territories of the Rocky Mountain region. The experienced farmers of Colorado are not looking for an increase in the rainfall. They are expecting, however, through irrigation, a marked and steady increase of terrene humidity, by reason of the saturation of the earth and the cultivation of the soil. That there is reason for their disbelief in the increase of rainfall, will be seen by the following tables, prepared at Colorado Springs, the first of which gives the rainfall of June and July for twelve years, from 1872 to 1883, inclusive:

Years.	June.	July.	Year.	June.	July.
	Inches.	*Inches.*		*Inches.*	*Inches.*
1872	2.07	2.69	1878	2.78	1.36
1873	2.24	2.00	1879	0.32	0.64
1874	1.21	3.35	1880	1.22	1.38
1875	0.43	4.12	1881	0.69	2.50
1876	1.10	1.16	1882	4.96	0.06
1877	1.93	0.33	1883	0.85	2.27

The second statement gives the total rainfall for eleven years, or from 1872 to 1882, inclusive:

Years.	Amount.	Years.	Amount.
	Inches.		*Inches.*
1872	18.95	1878	15.51
1873	11.73	1879	10.86
1874	13.45	1880	9.55
1875	17.25	1881	12.79
1876	20.12	1882	14.49
1877	16.38		

The extent of the irrigation works in Colorado may be seen by a glance at the following table, summarized from the report for 1884 of State Engineer Nettleton:

Water districts, canals, ditches, reservoirs, &c.

Water districts.	Number of ditches and canals.	Total number of cubic feet per second appropriated for priorities in each district.	Total number of reservoirs in each district.	Capacity in cubic feet.	Remarks.
No. 1	17	5,404.78	......	......	
No. 2	35	3,642.70	......	......	24 enlargements to 15 ditches in all.
No. 3	53	4,558.38	......	......	38 enlargements to 18 ditches in all.
No. 4	29	2,397.45	1	......	25 enlargements to 14 ditches in all.
No. 5	74	2,036.41	9	200,492,460	47 enlargements to 25 ditches in all.
No. 6	63	4,680.05	2	......	22 enlargements to 18 ditches in all.
No. 7	59	1,180.45	4	......	30 enlargements to 20 ditches in all.
No. 8	109	2,481.84	4	......	27 enlargements to 21 ditches in all.
No. 9	25	437.55	6	......	6 enlargements to 5 ditches in all.
No. 10	102	770.90	......	......	17 enlargements to 17 ditches in all.
No. 11	38	932.95	......	......	2 enlargements to 2 ditches in all.
No. 12	51	......	......	......	
No. 13	23	......	......	......	
No. 14	62	......	......	......	5 enlargements to 5 ditches in all.
No. 15	71	......	......	......	
Delta County, No. 16	87	974.00	......	......	
Chaffee County	13	83.34	......	......	

No. 4, 1 enlargement; No. 7, 1 enlargement; No. 8, 1 enlargement; No. 9, 3 enlargements to 3 reservoirs.

Passing from this detail of irrigation work and the results thereof, attention should be drawn to the fact that the discoveries so far made of belts of artesian water have been wholly along the flanks of the Sierra Nevada and Rocky Mountains. On the west flank of the first-named dorsal range and among the foot-hills of California; on the other and physically related eastern side of the eastern and continental range—the Rocky Mountains—as at Laramie, Wyoming, and Denver, Colo.; in the southern portion of the Staked Plains of Northwestern Texas, and along the western division of the Texas Pacific Railroad, artesian wells are being successfully sunk and utilized. The significance of this suggestion as to artesian water belts, and their topographical relation to the mountain ranges, and the possibilities of a system of conservation and distribution of water for industrial purposes, can easily be seen by reference to any topographical map of the West.

The discovery of an extensive belt of artesian water in the foot-hills region is likely to have an important influence on the problems that are being considered. The heavy snow precipitation, chiefly seen on the eastern flanks and the summits of the great ranges—which fact must be due to the influence of the Gulf of Mexico and the Atlantic Ocean, whence the winds bear moisture over the interior of this continent—will sufficiently account for the subterranean water supply developed at Denver, and partially found elsewhere, as at Laramie Plains, Wyoming, and along the southern edge of the Staked Plains of Northwest Texas. The questions to be solved in Eastern and Central Colorado and Wyoming, so far as the water supply is concerned, will be found to be of great future importance for the plains division, already referred to as lying between the ninety-eighth and one hundred and fifth meridians of west longitude.

THE PLAINS DIVISION.

Passing then to this division, the first one in order of statement, the last in that of description, the observer is met with another aspect of the problems under review. From the foot-hills of the Rocky Mountains, the plains, generally treeless, of Texas, Kansas, Nebraska, and Dakota, roll eastward and downward, like a great grassy sea, to the valley of the Missouri and the hydrological basin of the Mississippi.

It has already been suggested that within the Rocky Mountain region the imperfect meteorological records indicate, during such period of contemporaneous observation as they cover, a diminution rather than an increase of atmospheric humidity and precipitation. This is not stated as a fact to be decisively accepted, but as indicative evidence only. It seems to be accompanied also by other evidence to the effect that such diminution runs co-terminally with forest destruction. On the other hand is the striking statement, so suggestive of economic possibilities and utilities, that where settlement and cultivation have progressed to any marked degree, and especially where the latter has been aided by irrigation, there has been a decided increase of terrene humidity. Springs have increased in volume. The running waters are more regular in their flow and quantity. The increase in some places is a very noticeable phenomenon, as that of Salt Lake, for instance. With all these and other details, it is shown in California, Utah, and Colorado that wherever irrigation has been longest applied the necessity for the use of water by its means has diminished, owing to seepage from the ditches, and that capillary attraction which has heretofore been referred to. Under cultivation, then, the soil everywhere shows an increase in humidity. But this is offset by the destruction of the forests, which is a marked feature of settlement within all the intra-montane and Pacific coast divisions. On the other hand, the destruction of the native grasses and the substitution of other and cultivated varieties, have a marked effect favorable to the increase of terrene humidity. The eastern, or plains, division shows, however, a phenomenon of another character, and that is the movement westward, with the movement of population, of an increased rainfall. This precipitation is likened by the State engineer of Colorado to a wall pressed westward. At Fort Leavenworth, Kans., on the Missouri River, for example, the record of continuous observation covers a period long enough to admit of reliable deductions.

Prof. F. H. Snow, of the State University, Lawrence, Kans., who is properly regarded as an authority on meteorology, in a paper read before a scientific association, in 1884, after referring generally to the scientific hypothesis that this planet, as well as other worlds, is slowly passing through a series of changes which must ultimately bring it to the rainless condition of the moon, proceeds as follows:

> Although the general movement is in the direction of a reduction of the rainfall, there are, without doubt, local oscillations in consequence of man's influence upon nature, which in some cases result in a more rapid decrease than would otherwise be accomplished by the unaided forces of nature, and in other cases within limited areas secure an actual increase in the rainfall. I believe the State of Kansas has furnished an apt illustration of a change of the latter sort. The circumstances have been extremely favorable to such a change. Thirty years ago the Territory of Kansas was not occupied by the white man, and, if we except a few acres cultivated by the Delaware Indians, no portion of her soil had been turned up by the plow. Her entire area was included within the vast and almost unknown region of the "Treeless Plains" and the "Great American Desert." During that brief intervening period, more than one million people, chiefly of the agricultural class, have taken possession of her domain, and have already brought her to the very front rank of the States of the Union in the extent and value of her agricultural products.

> History affords no other instance of the permanent occupation of so extensive an area previously unoccupied by man by so large an agricultural population in so short a space of time. Here certainly, if human agency could anywhere affect climate, would such an effect be produced. Here assuredly, if settlement ever increases rainfall, will such increase be most marked and most unmistakable. That such increase has actually taken place I believe to be established beyond a doubt. It is a circumstance peculiarly favorable to the determination of the point in question that although the general settlement of Kansas by cultivators of the soil is of such recent date, reliable observations upon the rainfall had been made at the military posts upon the eastern borders for a sufficient period to make possible a satisfactory comparison between the rainfall before settlement and after settlement. The records at Fort Leavenworth cover the longest period, and enable us to compare the nineteen years immediately preceding the occupation of Kansas by white settlers with the nineteen years immediately following such occupation.
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> During the first period the average rainfall was 30.96 inches; during the second period it was 36.21 inches, giving an average increase of 5.21 inches per annum. Here we have an increase of nearly 25 per cent. in the rainfall, under such conditions as to necessitate the inference that such increase is chiefly, if not entirely, produced by causes connected with the introduction upon a large scale of an agricultural population into a previously uncultivated territory. The Fort Leavenworth records cover so long a period of time (nearly forty years) that the increased average of the second half of the period cannot be attributed to a mere "accidental variation." In the issue of Science for April 18, 1884, it is stated that "the supposed increase in the rainfall in the dry region beyond the Mississippi is not borne out by the returns of the Signal Service." But the records of the Signal Service, upon which this statement was based, include a period of only twelve years of observation, from 1871 to 1882, which is undoubtedly too short a period for either establishing or disproving the fact of a "secular" variation.
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> We have also called attention to the fact that causes which have a tendency to secure an increased rainfall have here been put into operation upon a grander scale than in any other portion of the dry region west of the Mississippi. But the fact of an increased Kansas rainfall does not rest entirely upon the Fort Leavenworth observations. There are other stations in Kansas whose records cover a much longer period than that of the longest established regular station of the Signal Service. There are the thirty years' records of the United States military post at Fort Riley, the twenty-four years' records of the State Agricultural College at Manhattan, and the seventeen years' record of the State University at Lawrence. If these several periods of observation be divided into two equal parts, in each case it is found that the average rainfall of the second half is notably greater than that of the first half. At Fort Riley the increase amounts to 3.05 inches per annum, and at Manhattan to 5.61 inches per annum, and at Lawrence to 3.06 inches. Expressed in per cent., the rainfall of these three stations has increased in the second half of each period of observation—at Fort Riley, 13 per cent.; at Manhattan, 20 per cent., and at Lawrence over 9 per cent. If the increased rainfall could be shown by the records of a single station only, or if the several stations, with sufficiently long periods of observation, exhibited discordant results, some indicating a decrease, while others indicated an increase; or, if even a single station indicated a diminished rainfall, the fact of a general increase would lack satisfactory demonstration. But the entire agreement of the four stations whose records have been used in a discussion of this question, seems to establish beyond doubt the fact of an increased rainfall in the eastern half of Kansas. There can be no reasonable doubt that the general settlement of the western portion of Kansas will have a similar effect upon its rainfall, but it is not reasonable to expect that Western Kansas will ever boast of a rainfall equal to that of Eastern Kansas. So long as the eastern half of the State remains to the east of the meridian forming the western boundary of the Gulf of Mexico, the south winds will cause it to receive much larger supplies of vapor for condensation into rain than will be received by the western half of the State, which lies beyond the immediate track of the vapor-laden winds. It must be remembered that climatic changes are exceedingly gradual, and a rain deficiency or excess for a single year, or for two or three years in succession, must not be considered as invalidating the law of general averages.

When settlement began on the line mentioned by Professor Snow, and west thereof, the average annual precipitation did not exceed 14 inches. It now ranges as high as 18 inches in the eastern portion of that section. This amount is, of course, far short of the full needs of industrial life; yet the column of settlement is moving west in both Kansas and Nebraska in a slow but almost solid wall. In Dakota this westward movement is now more rapid, but has not continued long enough for reliable deduction. In illustration of the views of Professor Snow and others whose evidence will be given, the following facts are of importance: Within the western or "dry" half of Kansas no white population was in 1860 recorded by the Federal census enumerators. In 1870 the total population in the same region was given by the ninth Federal census as 5,169. In 1880 the tenth census records it at 165,000. In the State Agricultural Report (biennial) for 1884 returns from thirty organized counties west of the ninety-eighth meridian are given. The unorganized ones are also growing steadily, and in the case of the southwest counties, where irrigation has been adopted, the increase is very rapid. The totals are:

Population	191,226
Acres under fence	2,840,979
Acres under cultivation (grain and tame grasses)	2,233,723
Number of cattle, sheep, &c	1,239,662
Pounds of wool clipped (1883)	1,726,443
Number of orchard trees	2,823,782
Number acres in small fruit	1,660
Number of acres in forest trees (planted)	29,367
Value of all marked meats, wool, and dairy products; also, poultry, eggs, &c	$5,338,825

The State valuation was put in 1885 at $550,000,000. The valuation in 1860 was $31,000,000; in 1865, $72,000,000; in 1870, $188,000,000; in 1875, $242,000,000, and in 1880, $321,000,000. Finney and Hamilton are the extreme southwestern counties of Kansas, lying in the valley of the Arkansas River. The river flows nearly through their center from west to east, with an average fall of about 7 feet to the mile. The valley varies from 1 to 5 miles in width, and is almost as level as a floor. On the north an irregular line of bluffs separates the bottom from the uplands, while the southern edge of the valley is marked by a succession of grass-covered sand-hills.

Beyond these is an extensive rolling table-land, not unlike the one north of the river. The general surface inclination is south and east. The average elevation of this portion of Kansas is about 3,200 feet above the sea. The atmosphere is clear and dry. The climate is mild and equable throughout the year, and very rarely do cattle and sheep on the open range need shelter from the weather. The soil is a sandy loam, varying from 2 to 4 feet, with a subsoil of light porous clay on the uplands and of tough impervious clay on the bottoms, the larger porti on resting on a limestone foundation. It is rich in organic matter and has a rare capacity for storing moisture.

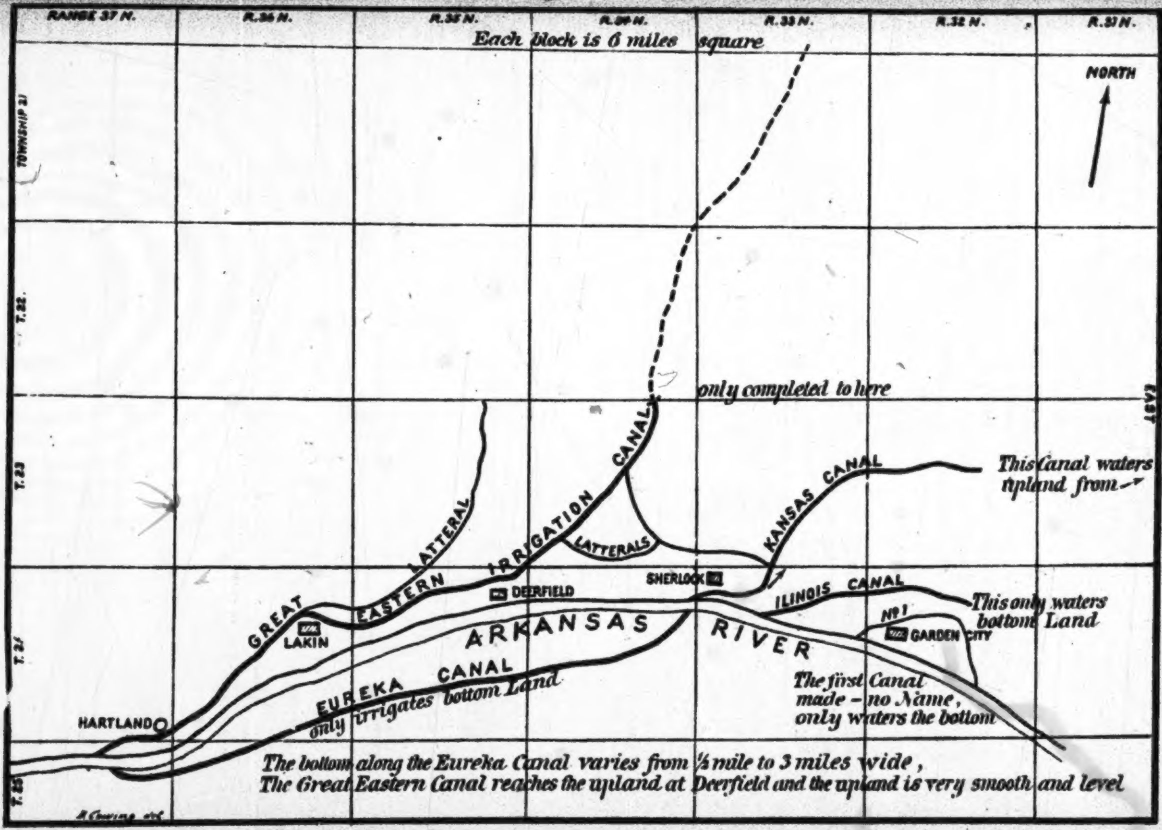
In March, 1882, not a section of railroad land in Finney County was sold. Six months later 50,000 acres had been disposed of to actual settlers. The soil was richer and deeper, if possible, than that of Eastern or Central Kansas, but the light rainfall had been a drawback to general farming. Throughout the western belt of counties in this State the rainfall is insufficient to justify agriculture. Irrigation, it had long been predicted, would redeem the country, and as the first experiment was a success, it has been continued through four years of extended work and profit. It is doubtful whether there are any localities where the contour of the surface is so favorable for a system of ditches as in the Upper Arkansas Valley. The river is a broad and shallow stream, flowing between low alluvial banks, which, with its descent of 7 feet to the mile, renders it easy to carry the ditches upon the uplands. Where the agricultural value of the soil depends on irrigation, the stream flows within a narrower channel, making the fall greater, and during the months when crops are dependent on irrigation the snows in the mountains keep the channel filled with an abundant stream. For land so low as that in the Arkansas Valley, the mode of irrigation known as the bed-work system is in use. The main ditch runs along the upper side of the tract, from which a number of shallow ditches conduct the water across the field, and this is further distributed by furrows connecting the secondary ditches.

The first irrigating canal in Kansas was dug in 1880. A ditch 8 feet wide, 2 feet deep, and 4 miles long was constructed, and although it was not completed until late in the spring of that year, the success of the experiment was far beyond the most sanguine expectations. The following year a joint stock company bought the Garden City ditch, enlarging the main canal to 16 feet, extending it about 8 miles, and constructing two additional branches. The ditch now extends 20 miles and has a capacity for watering 10,000 acres of land. The Deerfield ditch leaves the river 13 miles above Garden City. The works at the river consist of a wing-dam of sod to deflect the current into the canal, which has a sluice-gate to be used in shutting off the water, and a waste-gate to allow the water to pass down the river when shut out of the canal. The canal is about 4 feet deep and 40 wide at this place, but decreases in width and depth as laterals are taken out, till in the neighborhood of Garden City the branches are not more than 2 feet deep and 10 feet wide.

In the spring of 1881 a canal known as the Sherlock was surveyed to traverse the valley to a point north of Garden City. Eight miles had been constructed when the Deerfield and Sherlock consolidated. This company has under construction a ditch, which, with its branches, has a length of 30 miles and a capacity for watering 20,000 acres. The present canals and ditches have a length of over 300 miles, and for water service cover an area of about 600,000 acres. [See diagram.] The capital invested aggregates over $500,000. The land thus irrigated now sells at from $4 to $10 per acre. The population of this valley, within the irrigable area not already included in the totals given, will not be less than 3,000 persons. The population in the unorganized counties, not given, may be estimated at 5,000 persons. The total population of that portion of the State in which it is assumed that the rainfall is insufficient for agricultural settlement is not less than 196,000, all of whom live on and cultivate the land.

Western Nebraska, to the north of Kansas, equally shows, and perhaps in even a more marked way, the peculiar western movement of the rainfall, to which attention has been called as characteristic of the plains division. Professors Aughey and Wilbur, of the State University, and ex-Governor Furnas, of that State, all of them recognized authorities, declare that Western Nebraska and Eastern Wyoming, therefore, will show a steady climatic change. Professor Wilbur regards the rainfall as comparing favorably with that of European countries. A soil that is not cultivated, he says, is dead, or arid in character. He holds that there is no such thing as a desert in any part of the plains region; that ordinary well water will be found in all directions, and that artesian water is also obtainable. He says:

> The under soil presents a saturated stratum of 8 feet in thickness, upon which capillary attraction acts. When a settler on the frontier builds his sod house, or roofs his dug-out with sod, he is sheltered from the rain. The thatch of sod throws off the rain which falls on it. Even so with the unbroken prairie. It is thatched ground. The rain falls but penetrates not. It may come in ample abundance, but as regards the land on which it falls, it is mostly wasted. It rushes off into the drains, through the drains into the creeks and rivers, and from the rivers to the sea. When the plow of the husbandman breaks the sod the thatch is taken from the earth. Thenceforward the rain that falls largely stays. The absorbent soil of the prairie drinks up the moisture, and, for five or seven years of cultivation this absorbing process may go on,


RANGE 37 N.
R.36 N.
R.35 N.
R.34 N.
R.33 N.
R.32 N.
R.31 N.
NORTH
EAST
TOWNSHIP 21
T.22.
T.23
T.24
T.25
GREAT EASTERN IRRIGATION CANAL
LATTERAL
LATTERALS
KANSAS CANAL
ILINOIS CANAL
Nº 1
EUREKA CANAL
ARKANSAS RIVER
HARTLAND
LAKIN
DEERFIELD
SHERLOCK
GARDEN CITY

Each block is 6 miles square

only completed to here

This Canal waters upland from →

This only waters bottom Land

only irrigates bottom Land

The first Canal made – no Name, only waters the bottom

The bottom along the Eureka Canal varies from ½ mile to 3 miles wide,
The Great Eastern Canal reaches the upland at Deerfield and the upland is very smooth and level

S Mis 15 49.2

> until the ground is thoroughly saturated and has taken up its plenum of water for the uses of the farm. I have talked with hundreds of farmers upon the frontier, and I have found this to be their experience—a gradual yet rapid development of the resources of the soil by the increase of moisture in its various forms, which follows upon cultivation. As cultivation extends the characteristic growths of the prairie change. The stunted buffalo grass is displaced by grasses of a richer growth. Trees spread out from the river bottoms, and the land which was known to the traveler before the farmer settled upon it would be known by him no longer.

One of the most notable among the processes of reclamation is seen in the cultivation of timber. It is stated that since the passage of the timber-culture act (a law under which a settler receives 160 acres additional to the homestead of the same extent, on condition of planting 10 acres thereof in forest trees) a great area has been set out. The extent of this arboriculture can be seen by remembering the fact that over 29,000 acres were reported in 1884 as planted with growing timber in Western Kansas alone. In Nebraska, in 1884, there were set out 4,435,000 trees and over 2,000 bushels of tree seeds were sown. Up to July 1, 1884, the area reclaimed under the timber-culture act, within the States and Territories herein named, was 16,961,742 acres. If the law has been obeyed in the past there is now growing an aggregate of 4,240,433 acres of forest trees. If this is reduced, for fraudulent entries, by one-half, we shall still have an area of over 2,000,000 acres. The following tables, furnished by the General Land Office, are illustrative of the progress of occupation up to the date given within the great area under consideration in this report:

Number of entries under the timber-culture act of 1873 *from July* 1, 1874, *to June* 30, 1884.

States and Territories.	Number of entries.	Acres.
Arizona	145	20, 376. 85
California	2, 046	276, 216. 42
Colorado	2, 414	347, 719. 74
Dakota	42, 667	8, 246, 304. 66
Idaho	1, 804	238, 001. 13
Kansas	24, 666	3, 938, 040. 45
Montana	1, 371	180, 509 21
Nebraska	25, 031	3, 553, 479. 64
Nevada	33	4, 559. 79
New Mexico	377	51, 856. 78
Utah	285	34, 846. 67
Wyoming	448	63, 830. 98
Total	101, 287	16, 961, 742. 32

Desert-land entries under act of March 3, 1877, *and from said date to the same in* 1884.

State or Territory.	Original desert.		Final desert.	
	Number of entries.	Acres.	Number of entries.	Acres.
Arizona	347	154, 431. 26	45	17, 284. 30
California	1, 126	383, 548. 55	119	32, 547. 57
Dakota	22	18, 101. 00	1	300. 00
Idaho	563	169, 915. 79	65	17, 359. 07
Montana	1, 294	482, 281. 07	262	72, 598. 31
Nevada	563	100, 412. 37	102	25, 941. 20
New Mexico	429	121, 367. 60	16	5, 247. 03
Utah	943	188, 894. 17	228	31, 955. 30
Wyoming	1, 904	774, 096. 69	138	41, 030. 47
Total	7, 191	2, 453, 048. 50	976	294, 264. 15

Exclusive of these two classes of entries, designed to encourage the reclamation of land by arboriculture and by irrigation respectively, and also exclusive of homestead entries, there were in the ten fiscal years between 1874 and 1884, 9,074,781 acres taken up under the pre-emption acts, and 11,748,355 acres selected on the railroad lands reserved by the United States as within the limits of construction grants.

PRINCIPAL IRRIGATION WORKS.

COLORADO.

Dam at head of North Poudre Canal.—This dam is 30 feet 6 inches high in the center, and 150 feet broad at the top, and is formed in two parts. The face, which gives the necessary stability against floods, consists of crib-work and stones; the back, which renders the dam water-tight, is a vertical panel, or diaphragm of timber, backed with earth, small stones, gravel and mud, thrown in without puddling. The crib-work is formed of round logs 10 inches, at least, in diameter, joined at ends, as in ordinary log huts, with dove-tail or tongue joints. The cribs are 10 feet long on the face, and are fastened together with 18-inch tree-nails, 2 inches in diameter. The cribs are radiated to form, when laid close together across the stream, curved tiers of 200 feet, 216 feet, and 232 feet radius on the face. There are three of these tiers 6 feet asunder. The interior of these cribs, and the spaces between the stones, and the interior surfaces, are faced with large selected blocks of stone, carefully laid so as to overlap each other like slates or tiles of a house, and without mortar. The arrises are protected by 12-inch square balks, securely bolted to the cribs. The timber diaphragm is carried 4 feet higher than the cribs and stone work of the tallest tier, to form a slash board, which can be removed in sections in case it is found liable to be damaged by ice. The center portion of the dam for a length of 60 feet is carried 2 feet higher than the sides, to throw the bulk of the stream onto natural benches of solid quartz rocks on the sides, and thereby to protect the greater part of the face, and especially the toe in the center of the stream, from the abrading power of the water.

The total cost of this dam was $7,250. The dam was founded on stone and débris, the depth of which had not been sounded, but it was hoped that the clay thrown in the back of the dam, combined with the silting up of the river, would have the effect of stopping the flow of the water, and the result justified the expectation. This dam is not intended for storage purposes, but is simply a weir for raising the water high enough to enter the flumes and tunnels. The canal regulators are ordinary sluices, inserted in the flumes about 100 feet below the dam.

The objections that are urged against timber being used are met by the fact that the massive stone, or masonry in cement, which would have been requisite to secure the mass of material used would have been too costly. The cost, $7,250, was very low for a weir 144 feet long, but the foundations were not necessarily extensive, and the source of supply of stone and timber was at hand.

Montezuma Valley, in Southwest Colorado, is now the seat of a great irrigation enterprise. It is described in current reports as follows: The valley is about 30 miles long, running from northeast to southwest, and is nearly 10 miles wide. The water is to be taken out of the Dolores River at the northeast end of the valley. The State has located about 26,000 acres of land in the valley, and probably about 10,000 or 15,000 acres have been located by actual settlers, leaving between 50,000 and 100,000 acres yet unclaimed. The locations are principally at the upper end of the valley, near the tunnel. Mr. Nettleton, the State engineer, states that when the tunnel and the ditches are complete, there will be an abundance of water for irrigating the entire valley.

The Grand River Canal, in Western Colorado, has a width at the bottom of 35 feet, on the top of 50 feet, and a depth of 5 feet for the first 10 miles. The size then diminishes until for the last 2½ miles the width is 16 feet on the bottom and the depth 3 feet. The grade is .035 per hundred, or a little over 22 inches to the mile. The banks are given a slope of 1½ to 1, are 3 feet wide on top and 2 feet above the water surface. There are several drops, one of 6 feet, one of 13 feet, and one of 35 feet, while down the valley about 14 miles there is a final fall of about 14 feet. Just above the second fall a lateral canal has been carried out on the upper level, a distance of 17 miles down the valley, carrying 3 feet of water. The location of the head is so favorable that a full head of water can be taken out of the river at its lowest stage of supply, so that water in this canal, in consequence of the volume running in winter season, can be in operation the year around, a fact very important in Grand Valley, where it is assumed that late irrigation will be advisable and early irrigation a necessity for the germination of seed. The flumes, head-gate and waste-weirs have been built in the most substantial manner.

ARIZONA.

Dams at Phœnix.—These dams are formed of stakes, brush, and bowlders, rendered water-tight by filling in, up stream, with gravel and sand. Stakes are first driven across the channel, and between these bundles or fascines of willow trees about 3 inches in diameter at their butts are laid, with ~~butts~~ down stream, and weighted with a layer of bowlders; tule reeds in bundles are also used, mixed with willow and cottonwood tree. In alternate layers the dam is built up to the height of 5 feet. The willows sprout and the whole forms a mass of living brush and bowlders. When the current is too strong for a man to withstand while driving stakes, cribs are made and floated out and sunk, as was done with the fascine dam at Merced Canal head, in California.

The Arizona Canal weir across the Salt River at Phœnix is of rubble and crib work, and is 173 feet long and 6 deep at most. The banks are of rock. The mode of constructing the weir was to throw in stones of one to three tons weight, from a pontoon moored up stream right across the weir, until a bar was formed, which caused the water to spill over it the whole width of the channel. A bed of shingle 3 feet thick over the rock bottom has been scoured out as the blocks of stone obstructed and contracted the flow until all rested on the rock bed. The water flowing between the blocks became choked with shingle to the original level of the bed. Cribs, 12 by 22 feet, consisting of three 24-foot 12-inch logs, each 6 feet apart, across which four 14-foot 12-inch logs, about 7 feet apart, were secured by iron bolts spiking them together. Between these 14-foot logs 2-inch planking was spiked to the three longitudinal logs, forming a platform or floor.

These cribs were built to the height corresponding with the depth of the water where they were to be sunk and floated out, guided by the pontoon, which was so moored that it could traverse the whole face of the weir. On being placed in position the cribs were loaded with stone until they sunk to the bed in the desired position, and were then filled up to the water's surface. The cribs were placed diagonally to the face line of the weir so that they overlapped. Fascines made of willow, 2½ feet in diameter, were filled with stones. These were made on the pontoon and dropped into the water in the position, they were to occupy, being in the direction of the current, one end touching the crib-work along the whole bed; another series of fascines, forming five rows, were then laid across the stream against the upper end of the first series. Over these fascines bowlders and gravel were deposited, as also between the rock breakwater and crib up to the level of the top of the crib-work, 16 feet above the bed; 24-foot fascines are then laid over the fascines and parallel to the stream, overlapping the bowlder and shingle, filling and binding it together.

The bowlder and gravel filling is continued 8½ feet higher, at which level a finishing layer of fascines 10 feet long is laid, over which the water passes. The cost of this weir and head-works is $10,000, including $2,000 expended in a previous effort which failed. Besides this weir there is another, a waste weir, forming a portion of the canal head-work, its use being to keep the head-gate clear of sand and shingle. It is at an angle to the canal head-gate, and its gates are kept open 3 inches, so that there is a constant rush of water at the floor level, carrying any deposited material away.

CALIFORNIA.

The Riverside dam is a brush and sand one, formed by driving 3-inch poles or stakes in the bed across the stream, and between them packing in willow and cottonwood brush, with the branches up stream; the water scours out below, and the brush is pressed down and more is added until the whole stream is passing through brush. This soon causes a deposit of silt and forms a solid bank, over which the excess water falls. It is sometimes necessary to construct a temporary dam to retard the flow, and then make a more permanent one above it. The off-take forms a wing of the dam, gradually narrowing to the canal. The Mexicans, who are very expert at this work, are generally employed. The dam for the off-take of the upper canal is constructed in the same manner, and the wing and dam are continuous.

The wing-dam at Los Angeles, constructed across the river for supplying the irrigation canal, is made as in India; first stakes are driven in across the stream, brush is laid between them and the sand thrown in, and then other layers of brush are added. When the current runs along the face of the dam, branches with their leaves projecting into the current are thrown loosely out, arresting the current, and causing a deposit of sand, and so strengthening the work. Here the work was done by Mexicans.

Merced River dam.—The original dam, a portion of which remains, was constructed on the crib principle, the cribs being formed of triangular frames connected by longitudinal planks, forming a floor and sides about 2 feet high. The cribs were made in about 20-foot lengths, floated out into their positions in the current by means of ropes, and sunk by bowlders filled in over the floor. Purlins were fastened to the sloping beams, on which 2-inch planking was nailed. Bowlders and shingle filled in up stream prevented the water passing underneath. The connection with the bank was defective, and resulted in the dam being breached at the left bank and 200 feet being carried away, but the breach has been stopped by a temporary dam of brush and bowlders

This had to be effected whilst the discharge was about 500 cubic feet a second, and was done in the following manner: Cribs were made of 10-foot by 4-foot 4-inch lumber, and were floated to equi-distant points in the gap, and there sunk by being filled with bowlders, forming fixed supports or piers about 15 feet apart. They were filled with bowlders from the bank by means of planks extending from it to the crib, the one next the bank being filled first, and so on.

Fascines, 2 feet in diameter, were made, 40 feet longer than the gap to be closed. These were made along the bank some distance up stream. They were easily rolled into the water and towed across the stream, so as to overlap the remaining end of the dam 20 feet, the remaining 20 feet being carried along the bank to be deposited in a trench cut into the bank down to 2 feet below water level. The fascines floating down are easily controlled and guided to the position they have to occupy when stopped by the cribs. Here they are pushed down to the bed and are laid there in order and weighted with bowlders.

Then fascines, 30 to 60 feet long, are laid crosswise on these, weighted by stones. More longitudinal fascines are placed on these. The top layer consists of short fascines lying up and down stream, which are filled with stones and covered with the heaviest procurable bowlders. The connection with the bank is somewhat similarly made and requires particular care. The fascines can be made of any specific gravity greater than their own by placing stones in their body. They are bound with wire. The cribs are of no use as soon as the fascine work is completed, and large bowlders filled in down stream, to break the action of the falling water, but they are not removed, and may probably serve as piers to enable repairs to be made.

Storage dams.—The storage dams for temporary purposes, such as hydraulic mining, are usually formed of timber cribs filled with stones, or of dry-stone masonry. For the permanent storage of San Francisco water supply, where the first cost would not influence the selection, earthen dams were adopted because the foundations were found to be of clay, at a depth of 47 feet, and not safe for masonry, on account of its liability to compression. The Pillarcitos reservoir dam, which retains 1,000,000,000 gallons, is framed of earth. It is 640 feet long on top, 26 feet wide, and 95 feet high. A puddle-pit is sunk below the base of the dam 46 feet. The inner slope is 2¾ to 1 vertical, and the outer 2½ to 1. This dam has been built twenty-one years.

The San Andreas dam and reservoir is of nearly identical dimensions with the Pillarcitos, excepting that the slopes are 3 and 3½ to 1. It has developed no defects, although constructed in the same manner. With 89 feet depth of water against it, it will retain 6,690,000,000 gallons. The great depth of puddle-wall in both dams was necessary to intercept subterranean drainage through gravel and bowlder strata, indicating the beds of the valley drainage in earlier periods. The precaution of sinking this deep puddle-wall was justifiable where a town supply was the object of the work. The puddle was continued up to the top of the dam, not in the form of a separate wall, which has been the frequent cause of failure of dams, but intimately bounded with inner and outer masses forming the slopes.

The dam was formed in layers sloping toward the middle, the base having been first excavated to form a hollow across the valley, this material being used to form the outer portion when of non-impervious material. The most impervious material was used for the interior mass, forming a puddle core, the exterior layers overlapping its layers alternately.

In the Pillarcitos reservoir dam waste weirs are formed capable of passing 800,000,000 gallons daily; one is a tunnel through the eastern bank, the other is built of wood. The natural drainage basin is 4 square miles. This is increased by a wooden flume, 42 inches by 16 inches cross-section, which brings water from several small tributaries that join the main stream below the dam, and which increases the drainage area one-fourth. The excess water from this reservoir goes into the San Andreas to the extent of 26,000,000 gallons daily.

The construction of stone dams for temporary storage uses about three times the quantity of stone required by a properly proportioned profile of a cement masonry dam. The faces are laid up by hand and the interior filled with stone without laying. The beds of the stones in the wall on the water face are sometimes placed perpendicularly to the slope, instead of horizontally. The cost of such a construction will, in favorable cases, be much less than that of masonry laid in cement, the cost of masonry laid in cement being from $20 to $25 per cubic yard, and the dry-stone masonry costing from $2 to $3.50 per cubic yard.

The prevention of leakage is secured with more or less success in different cases by a lining of plank laid in timber, built in the inner slope of the dam and carefully fitted to the bed rock. The joints may be calked, or if seasoned planks are used, the swelling by the water sufficiently closes the joints. Earth is sometimes used in the inner slope to secure tightness.

The Fordyce Valley reservoir dam on the Yuba River, Nevada County, is a construction of dry-stone masonry as above described. It is 105 feet high, with the inner slope of 45°, and an outer batter of 4 vertical to 1 base. The base of the dam at its widest part is 165 feet. The area of the reservoir thus formed is 1,200 acres. An example of a masonry in cement dam, recently constructed, retaining 8,000,000,000 gallons, is the Bear Valley Reservoir dam in San Bernardino County, California. It is across a gorge with precipitous rocky sides into which the dam is abutted, forming an arc of a circle with a radius of 167½ feet, arching up stream. It is 17 feet at its base, 60 feet high, and 3 feet thick by 300 feet long on the top. The whole is built of large granite blocks set in Portland cement, the interstices being filled with concrete which is thoroughly consolidated. It contains 3,300 cubic yards of rock, set with 1,300 barrels of cement. The cost was $60,000. The outlet is through a culvert beneath the dam, closed by a gate 21 by 24 inches; it discharges into a basin whose outlet is over a weir for the measurement of the discharge. On one side of the dam is an overflow channel in the rock. Its floor is 4 feet lower than the crest of the dam.

The lake formed by this dam will be 5 miles long, with an average width of about 1 mile wide and a depth of 12 feet. The drainage area is 60 square miles, and one-third of the smallest rainfall recorded here will assure the filling of the reservoir. It is capable of discharging 120 cubic feet per second continuously, but it is intended to supply only 72 cubic feet per second, allowing the balance as a reserve in case of drought. For the irrigation of fruit trees and vineyards this will suffice for 400 or 500 acres per cubic foot, or about 30,000 acres in all. The timber and stone constructions for the temporary storages are of pine logs, treenailed at each intersection, set 6 feet apart, forming cribs measuring about 10 by 6 from center to center. These are filled with stones. The water face is either planked, as in the dry-stone dam sections, or instead of planks small trees are used and calked with bark. These works are always in mountain gorges, on rock beds, to which they are secured with iron bolts, fox-wedged and set in sulphur.

Subsoil dams are frequently constructed in California, with the object of cutting off the subterranean flow of water in channels whose beds soon become dry on the surface. It is first ascertained by sinking shafts across the channel whether water is thus passing subterraneously. This will be observable in some cases by floating substances traversing the shaft, but if the flow is very slow it may not be detected by this means, and coloring the water with a dye will show it by a replacement of the colored by pure water passing through the shaft. A subterraneous water flow is frequently brought to the surface by impervious strata traversing its course. Localities in which this occurs are the best sites for weirs. It is not probable that such natural bars are to be found in the plains, far removed from the source of supply, and to produce them artificially in such situations would necessitate very deep and probably very extended walls. The trial shafts should therefore be made where the valley is well defined in character.

Of course these submerged dams can only bring water to the surface of the channel where the latter is of sand or gravel through which the water would rise, forming an artesian supply. Where the surface of the bed is of sand, in which the water could be again lost, the elevated water would of course be diverted to an impervious channel provided for it. Where such subterranean water can be intercepted a considerable supply might be expected for some months after the water ceased to flow previous to the interception, for doubtless in many cases a considerable proportion of the rainfall is absorbed and given off gradually to subterranean strata.

Subterranean currents have also in several instances been interrupted by means of tunnels run in from the surface 2,000 and 3,000 feet, the flow being planked to form a flume and the water then conducted to open channels. Tunnels of this character are at Ontario and at Passadena, where a second tunnel was driven at a higher level, completely cutting off the supply from the first enterprise. At Riverside it has been ascertained that there is a large subdrainage in the low land forming the bank of the river. A level channel for half a mile, cutting across this drainage so that the flow shall be intercepted, will give perfectly clear water, sufficient for the canal supply. Should half a mile not be sufficient it can be extended.

Flumes are used where it would cost considerably more to convey water in an excavated channel, or where the soil is gravelly, and the loss by percolation would be great. Ravines are crossed by flumes or pipes. The objection urged against flumes is their continual cost for repair, and danger of destruction by fire. Where they are used, and practicable, they are set on a heavier grade than channels 30 to 35 feet per mile, and are of proportionally smaller area than channels with less grade. They should be constructed in straight lines if possible. Curves where required should be carefully set out, so that the flume may discharge its maximum quantity. Many canals have miles of fluming in California. In the ordinary style of construction, sills, posts, and ties support and strengthen the work at every 4 feet. The posts are let into the ties and sills. The sills extend 20 inches beyond the posts, to which side-braces are nailed to strengthen the structure. Where flumes are not supported on trestles, but rest on an excavated ledge, it is desirable still to use the stringers, which should be placed just outside the posts, so that water leaking from the sides will drop clear of them. Main supports, such as trestles, are placed 8 feet apart. Planking should be either redwood or heart sugar pine

A flume at Riverside is 900 feet long, the section being 8 feet by 2 feet 8 inches, the sills rest on concrete blocks made *in situ*, molds being over the spot where the block is required, and concrete consolidated into it. Its greatest height is 42 feet; the total cost, $6,200; wastegate at the upper end cost $200. Thi is necessary in case of repairs being required. The connection with the land at either end is 15 feet long, with sets of flanges projecting 5 feet on either side, and a 16-inch plank underneath. The joints are covered with a solution of asphalt in turpentine, which is elastic, and does not crack. This protection would not be necessary if carefully-joined redwood were used.

A flume at Los Angeles, constructed by Mr. F. Eaton, is both economical of material and strong in design. Here Oregon timber was used. The joints were left open one-sixteenth of an inch, and champered, and the inside swabbed with asphalt. The planks were 16 feet long, breaking joints at 8 feet. Cattle troughs are made on the same plan from 8 to 16 feet long.

Flumes are often constructed, instead of small channels, where the soil is porous and the quantity of water limited. These are made of three planks, in lengths about 10 feet, and butt-jointed (the joint being covered and connected by a 3-inch by 1-inch piece), and are laid to a grade of 10 feet to the mile or more. Holes are made in them opposite each tree or furrow that requires water, a stop is placed in the flume below the length to be irrigated, and the plugs removed from the holes when the water is to be delivered.

The Bear River Canal flume is 500 feet long, with section of 5 feet by 3 feet, and a fall of 10 feet per mile. Flumes are extensively used in hilly districts for drainage across the land, and a waste flume is inserted opposite the drainage, permitting the water in excess of the channel's capacity to escape. A flume is sometimes carried inside a larger one, the smaller one delivering the water at a higher level, or to another irrigator, so that the two supplies may be kept separate.

The asbestine system.—The inventors of this system hold that in a region where no rain falls during the long summer, the only proper way to irrigate orchards, vineyards, &c., is to apply the water below the surface of the ground, keeping the surface dry. The asbestine system consists in conducting the water in concrete pipes below the reach of the plow along each row of trees. At each tree a plug is set in the upper side of the pipe, each plug having a small hole, through which, and nowhere else, the water escapes, falling on the outside of the pipe and being taken into the soil by capillary attraction. It saves from three-fourths to nine-tenths the water used in surface irrigation. It is under perfect control and can be applied wherever irrigation is needed.

There is no need of summer cultivation, either before or after irrigating. The surface of the ground is always dry in summer, hence exempt from the unavoidable chill of surface irrigation. The soil is never excessively wet and cannot bake, but remains moist, loose, and at nearly uniform temperature, promoting a long summer growth. Anything that the soil lacks as plant-food (manure, lime, &c.) can be easily, directly, and economically applied in liquid form. The pest of the vineyard, phylloxera, can be thus easily reached. No grading is necessary, as the system works as well on hillsides and undulating land as on ground uniformly sloping.

If, through carelessness, muddy water is let into the pipe, and sediment collects, one or more of the lower plugs can be taken out, and the water passed rapidly through. The pipes will thus be cleaned. If the water is kept in motion, the sediment it contains should not be deposited.

The following brief notice of this system, as found in use on the vineyard and fruit-farm of Mr. C. L. Briggs, in the Sacramento Valley, is from a small volume by Mr. Dow, of Melbourne, Australia, and occurs in an account of a visit paid by Mr. Dow to the Briggs farm:

> The pipes, 4 inches in diameter, are made on the place by an ingenious machine, from cement and fine gravel, in the proportion of three-fourths of the latter to one-fourth of the former, and are laid at a depth of 20 inches down the center, between each second row of vines, with an opening for the escape of the water in the upper side of the pipe every 30 feet. The pipe-making machine is so constructed as to travel along the trench, making, and laying the piping in one operation, after which, the earth is covered in with a guard over the vent-holes to prevent choking.
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> The water supply, raised when required from a neighboring stream by steam-engine and centrifugal pump, is commanded by sluice-doors at various points, to admit of the water being laid on or shut off at pleasure; but excellent as the system is in theory, Mr. Briggs has not yet managed to get it to work with thorough satisfaction.
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> Mr. Holt, of Riverside, has devised a different mode of letting the water escape from the pipes. To prevent the holes in the plugs becoming occasionally closed by roots finding their way into them, a section of about 6 inches long is cut out of the continuous pipe where the plugged hole would be, and a square hole, about 6 inches by 6 inches, sunk below the gap in the pipe. A tile, in the form of a saddle, 9 inches long, covers the gap, and the water escapes between the two surfaces. The advantage of this plan is that if roots do find their way between the two faces they are easily cleaned away by cutting them. The hole below the gap catches any silt that may pass down the pipe. This most economical system of irrigation should be especially suited to cases in which water is very scarce, as where it is raised by wind-power. The water will spread over a circular area of 16 feet diameter in four or five hours. Sub-irrigation is practiced largely in Japan.

Pipes and conduits.—Where water is scarce, and has to be conveyed long distances in channels excavated in the soil, exposing it to too great a loss, impervious channels and pipes of various kinds have been resorted to to convey it to land that was valueless without it. This has caused the adoption of a variety of materials to render conduits impervious, and of various modes of application of water by their means. The following impervious conduits are used: (1) Wooden flumes; (2) lined channels; (3) wrought-iron riveted asphalted pipes; (4) wrought-iron laminated asphalted pipes; (5) terra cotta pipes; (6) cemented pipes; (7) asphalt pipes.

Lined channels.—The Zanja Madre Channel at Los Angeles was lined with concrete, and had a cross-section of a segment of an ellipse, with a diameter of 5 feet and a depth of 3½ feet. The thickness of concrete was 6 inches. The ingredients were hydraulic lime, two parts; clean, sharp sand, three parts; pebbles, 1 inch in diameter, four parts; small stones, 2 to 3 inches in diameter, four parts; large stone, not exceeding 5 inches in diameter, four parts; cost $2 per lineal foot.

A tunnel conveying water to Los Angeles was lined on the bottom with concrete 4 inches thick, forming a semi-circle of 4 feet diameter. The cost was 75 cents per linear foot, with cement at about $4 per cask. Wrought-iron riveted and asphalted pipes are extensively used in Los Angeles County for irrigation. They are jointed, stovepipe fashion, and when not subjected to too great pressure are set with red or white lead.

Wrought-iron laminated asphalted pipes are made of two shells of sheet-iron. These shells are made of one sheet of iron 8 feet long, rolled and lapped 1 inch, and united by a composition solder. They are half the thickness of iron that would be necessary for the ordinary sheet-iron pipe. The inner shell is telescoped into the outer shell whilst immersed in hot asphalt, specially prepared, giving a thickness between the sheets one-sixteenth of an inch, or more, if desired, thus making an impassable barrier to corrosion from outside or inside. The outside and inside coatings are also substantial. This produces a solid shell 8 feet long, with an inner surface free from all excrescences.

The pipe is also made double, of one sheet, by rolling a sheet that is twice the width of the single sheet until the edges will lap with a thickness of iron between them; the lap is riveted. This is dipped in asphalt, but it cannot have the intermediate lamina of asphalt, which is the main advantage of the laminated over the single sheet-iron pipe. Both these descriptions of pipes are jointed end to end, an inner sleeve being fixed in the shop. In laying, the end is dipped in hot asphalt and an outer sleeve is also dipped and pressed on by a clamp over the point until the asphalt is set. Bends and branches are of cast-iron, as in the ordinary sheet-iron pipe, and the joints are made with cement.

The 4-inch laminated pipe has been tested up to 500 pounds per square inch. Its price is about 25 cents per linear foot. The double-rolled pipe is about 17 cents per foot. The construction of the latter is much simpler, and the asphalt has been found a perfect protection from rust, so there is no necessity for the lamination. Terra-cotta pipes would be excluded by their price, except for some special purpose, such as sewerage or culverts, for use under roads, &c. Concrete pipes, where good sand is obtainable, and no pressure is required, are extensively used.

At Ontario Colony, San Bernardino County, an irrigation enterprise has been started, which is ~~mainly~~ dependent on concrete pipes for conveying the water from the cañon. Thirty miles of 12-inch concrete pipe have been laid here, at a cost of about 43 cents per linear foot for making. The ingredients are cement, sand, and gravel, in the proportion of one of cement to four of clean, sharp sand, and gravel. The gravel may be as large as half the thickness of the shell of the pipe.

The pipes are formed in molds of sheet-iron. These consist of two sheet-iron cylinders, an inner and an outer, both of which can be expanded and contracted by means of a bar fixed parallel to the joint from which four arms project, connected with the outer edge of the joint so as to close and open it. Between these cylinders is a cast-iron ring, forming the base. This cast-iron ring is shaped to mold the end of the pipe to form a socket. The inner cylinder or core is kept central at its base by being inside the cast-iron base. It is centred above by hand until sufficient of the concrete mixture has been consolidated around it to keep it so. The filling is then completed, being put in in small quantities at a time, and consolidated with an iron rammer. The upper end of the pipe is shaped to form a spigot by means of a cast-iron ring that is worked round by hand. A 6-inch diameter 2-foot-long pipe is made at the rate of one length per minute by three men. Only as much of the mixture must be made at one time as can be used within ten minutes after mixing, or its setting qualities will be injured. The newly-made pipe is removed from the mold or the mold from it on the drying area, the base being left for it to stand on until sufficiently set to handle. In handling the larger-sized sections a clip with handles is used, and another for laying.

The pipes made with a mixture of one to four are not guaranteed to stand pressure, but with a slight increase, and well consolidated, they will stand a considerable head. They are cheaper than any other pipes when suitable sand and gravel are obtainable near the site where they are to be used. A continuous pipe-making machine, for making a continuous concrete pipe in a trench excavated to the required depth for sub-irrigation, consists of a cylinder of the size of the pipe required, in which an india-rubber core is moved backwards and forwards by a lever, the concrete material being thrown into a funnel fixed at right angles to the pipe-making cylinder. By this means three men can make over 1,000 feet of 2-inch piping in ten hours. This system is not much used.

Asphalt-concrete pipes are made as described for concrete pipes, and are superior to them, being perfectly impervious, and capable of withstanding much greater pressure. The proportion of sand to asphalt and the other ingredients could not be ascertained, but the quantity of the sand need not be limited, as in cement concrete, for the larger the quantity of sand used the harder and better the pipes. The pipes are united by heating them so as to form a continuous pipe, as strong at the joints as in another part. Where the ground is yielding they are laid on piles driven 6 feet into the ground, and a plank laid on top of the piles upon which the pipe rests.

The Highland Park Water-Works, Los Angeles, for irrigation and domestic supply.—The source of the supply is the Arroyo Seco, a torrent which runs a few days only after each rainfall, and springs, yielding during the dry months about .08 cubic feet per second. There are 400 acres supplied by the system, which must necessarily depend for its irrigation on the flood flow; hence a storage reservoir is necessary of sufficient capacity to store the rainfall as it occurs, to be applied to the land during the intervals of dry weather, which through the rainy season average about fifteen days each. Allowing 2 inches depth as the minimum for each irrigation, 400 acres would require eighteen and one-seventh million gallons. The reservoir capacity is 20,000,000 gallons, and is connected with the main pipe, so that any excess over the distribution flows into the reservoir, and of course when the supply from the source is less than the pressure from the reservoir, the distribution receives the water from the latter. The reservoir is therefore the head to which the supply pressure is due unless the reservoir main valve be closed, when the head at the source would furnish the pressure.

This system is capable of supplying 12 inches depth of water over the 400 acres during the year, in addition to the rainfall, which averages 12 inches, and falls between the months of November and May. The land thus receives 24 inches depth of water, which is ample in this country for most products required, excepting oranges and alfalfa. The main pipe is 8 inches in diameter, asphalted wrought-iron, and the distribution pipes are of the same material, and from 2 inches to 6 inches in diameter. Each lot takes its supply through a 2-inch pipe. The effective pressure is 40 pounds per square inch. The land is irrigated by furrows, and service-pipes are laid over the ground in some cases, so that each tree can be watered from a rubber hose into a check of from 5 feet to 12 feet diameter, according to the age of the trees.

The head works are temporary, consisting of a wooden trough 100 feet long. This is laid in the bowlder bed of the channels, with the top of the sides slightly below the bed line. It is anchored by cleats fastened to its bottom, that extend 3 feet from the sides. These are covered, and the trough filled with bowlders, the water flowing between the bowlders. The trough at its lower end is connected with a 10-inch cement pipe. The temporary wooden flume will be replaced by a perforated wrought-iron pipe that will extend 100 feet, 5 feet below the shingle and bowlder bed, the water being dammed back by a submerged weir, causing the water that the pipe is capable of carrying to be drawn off by it; the water will thus be filtered of anything that can now pass between the bowlders. The cost of this scheme was $21,300.

The Ontario colony.—This colony is an example of utilizing waste land and water to the maximum of benefit. It is situated on the sloping land from the foothills of the Sierra Madre Mountains, where San Bernardino and Los Angeles Counties join, the San Antonio Cañon or Valley giving a perpetual supply of water from the mountain snows in the summer, and from rain which falls on the lower slopes and hills in the cold months. The soil was analyzed and examined as to its productive capability, and found to be peculiarly adapted for the growth of vines and fruit-trees. The climate was also favorable. Having purchased the land and the water rights, the colonists distributed the water by means of cement pipes over the whole tract, divided into 10-acre lots, so that each lot should be supplied at the highest point. To accomplish all this has cost about $170,000. This includes roads, streets, railway station, hotel, college, dam, and 27 miles of pipes, masonry-lined channel and tunnel, iron pipes for supply of township, &c.

A dam diverts the surface water from the channel, but as a large quantity passes below the bed, a tunnel 3,000 feet long has been driven across this drainage and leads it into a masonry-lined channel, which is 6,000 feet long. The water is taken from this channel by the cement pipes, but a reservoir will be constructed to store the surplus water not required during the non-irrigating season, and the pipes will then connect with it. It is intended here to use the laminated wrought-iron pipe, preferring it to the single-shell riveted pipe. The water is delivered and measured from the cement pipes by means of a vertical connection, at which point a valve is fixed, consisting of a cast-iron plate, with an aperture the size of the pipe in it, and a groove for the valve to slide in. This valve is simply a plate of cast-iron with a wrought-iron lifting-rod. The tunnel referred to was decided on after sinking experimental shafts across the valley and then ascertaining that there was such a subterranean flow that a light substance, such as a chip of wood, would be carried to the bottom of the shaft.

This mode of intercepting water has been frequently resorted to with the most surprising results. The quantity of water used for irrigating by the pipe system is one cubic foot of water per second to every fifty acres. The value of 1 cubic foot of water per second where it can be applied, as here, to fruit-growing, is estimated at $50,000. The unit of measure is one-fiftieth of a cubic foot, and is termed an inch of water, and is measured by the discharge through an aperture 1 inch square in a 1-inch plank under a 4-inch pressure. The discharge of a stream for irrigating purposes is estimated for the mid-summer period, that is, from the 15th of July to the 1st of August, when it is at its lowest.

Calloway Canal, Kern County.—Stretching across the Kern River, a distance of some 600 feet, between the head-gate of Calloway and that of the Farmers' Canal, and secured at either end by substantial abutments of earth, faced with planking, is a movable weir for the purpose of diverting water at low stages. This weir is fixed upon a floor resting 3 feet below the bed of the river, upon anchor piling, protected from wasting and undermining by three parallel rows of sheet piling of 4-inch plank, driven into the sandy bed to a depth of 10 feet, one line of piling resting under each end of the floor and one under the center. Upon this floor are placed, at distances of 4 feet, movable bents, resting at an angle of 45 degrees upon braces properly tied. Pivots at the top of the bents are passed upward through holes in a continuous line of 2-inch plank, which serves as a foot-bridge in manipulation, tying the whole together, and in grooves provided on the upper face of the bents, 6-inch boards, in lengths of 12 feet, are slipped in the form of a dam to raise the water as necessity may require.

During ordinary high water all weir-boards are removed and the flood passes harmlessly through, and in case of an extreme freshet the structare would simply rise from the floor, fall to pieces, and float down stream, without causing any further damage or material expense of readjustment. The weir was built in the fall of 1884, upon the plans and under the superintendence of M. F. H. Colton, superintendent of the Kern Island Irrigating Canal, and has answered admirably the purpose for which intended. The cost cannot be given, though cheapness was one of the advantages claimed for it.

Distribution of water.—When large areas have to be irrigated, or when the supply of water is limited and labor scarce, time and economy of water have to be considered in preparing the land for receiving the water. The system requiring least labor is that of flooding, sluice-gates having merely to be opened and kept so until the required quantity of water has been supplied to the prepared area or "check." The quantity of water used in excess of what is just sufficient for the nourishment of the crop will be in proportion to the size of the area irrigated and the volume of water thrown on it; thus, the area of the check might be so large in proportion to the volume of water that the absorption would exceed the supply, when the water would only spread over a certain area. This area should be the maximum extent of a check, and it would be better if it were made smaller or the supply increased. This would cause it to be covered in a shorter time, and lessen the loss of water in excess of what is essential.

When the soil is compact the area of the check would be made larger than where it is absorbent; these conditions have to be considered in laying out the distributing channels. In the check irrigation from the Poso Canal, on the Kern Island farm, a portion of the distributing channels are placed one-fourth of a mile apart, and their banks form two of the bounding ridges or levees of the checks, the fourth boundary being a contour or level levee connecting the channel levees. The top of the contour levee must be 3 or 4 inches above the level of the opposite side, so that it can be covered with water to that depth. The levee should have a base of 20 to 1 vertical, forming a gentle swell in the land upon which the crop grows. The less the height of this contour levee the better, because the quantity of water spread over the land will be of a more uniform depth, and will interfere less with the plowing and harvesting operations. A height of 6 inches has been found best, with a base of 10 feet, but a height of 12 inches has been used. The crop then was lucerne.

The fall of the country here away from the canal is 12 feet per mile The levees were put into farm terraces, each 1 foot below the other, limiting the area or check to about 20 acres, which, in this soil, was considered the maximum for economy with the volume of water available—80 to 100 cubic feet per second. Smaller checks are preferable, as the crops produced by a short submergence are as good as those longer submerged, in which the waste must be greater. On more level land the check need not, of course, be so high to divide off the same area, and on land which is entirely level it need only have a height equal to the depth of the water applied at each irrigation. The low levees are less liable to be breached, and breaches are more easily closed when they occur. The crop growing over it protects it from being eroded, and renders it unnecessary to have the excess water against it passed on to the next by levee gates, or by making an opening, as the small depth of water would be absorbed before the crop would be injured.

The supply-canal is along the highest part of the land to be irrigated The distributaries are 16 feet at bed, with slopes 1½ to 1, the mean depth being 3 feet, and are closed at their offtakes by gates giving 15 feet waterway. There are stop-gates at intervals along the distributaries, by means of which the water is raised to cause it to be discharged on to the checks; these stops also act as drops where the fall of the channel is greater than the soil will stand. The check, or side-gates, of which there are two to each check, are from each distributary bounding the check, and have a waterway of 6 feet, with a depth of 5 feet from the top of the levee, the flow being 2 feet below the check-levee. They are capable of discharging 40 to 50 cubic feet per second, so that, with the gate from the other distributary, 8 cubic feet per second can be delivered on the 20-acre check, which would cover it to the depth of 4 inches in one hour; but it occupies about three hours, showing that there is a loss by absorption of 8 inches. As soon as this check is covered, the side-gates are closed and the contour-levee gate opened that passes the surplus water collected at the low part of the land into the next check, so that the excess of water in the first is neither lost nor allowed to stand and injure the crop. This extra supply expedites the covering of the second check, of which the side-gates are now opened and the process repeated.

Two or three checks are generally irrigated at the same time by one man. The checks that are below the drops in the distributaries, and cannot receive a supply from them, are irrigated from the check above, one or more extra levee-gates being inserted; the flooding of these checks, therefore, takes a longer time on account of the loss by absorption in passing through the upper check, consequently the checks below the drop should be of a less area than those receiving their supply direct from the distributary. The contour-levee gates should be put in on the higher points of the lower check, if possible, so that the water will flood this by flow instead of by inundation, which would require an increased depth of water over the whole check. The contour-levee gates have 4 feet waterway by 2 feet deep. These side-gates have frequently been washed out, although their floors are placed 12 inches below the surface, and have had to be protected down-stream by extending the floor and packing with trash; sand-boxes placed on the down-stream side would be the best protection; or, they should be widened and lengthened.

Proposed lowering of Tulare Lake.—The character of the irrigation and engineering projects under discussion in California finds illustration in the following newspaper dispatch, sent from San Francisco under date of April 12, 1886:

> A company of capitalists is being formed to carry out one of the most important irrigation and transportation schemes ever projected in this State, which will solve the question of transportation in the Upper San Joaquin Valley and open up nearly half a million of acres of land which are now under water, and half a million more acres, which for want of water are now little better than a desert.

It is proposed to permanently lower Tulare Lake to 15 feet below the present level, which will reclaim 375,000 acres, including swamp land, all now under water or subject to frequent overflow. This is to be effected by a canal of 12 feet average depth, which is to extend from Tulare Lake to a junction with the San Joaquin River at the head of navigation, distance about 40 miles north from the lake. The line of the canal will be through the present swamp which extends north from the lake. The level of the river at the junction is 48 feet below the level of the lake, and thus affords a sufficient fall for the discharge of the surplus water of the lake proposed to be drained. An additional outlet is also afforded by a projected west side irrigation scheme, which is to take water from the canal for the irrigation of over 400,000 acres of valley lands, the proposed canal forming, with Tulare Lake, a continuous inland water-way of over 70 miles. It is expected by its affluent discharge of water into the Upper San Joaquin River to so improve navigation as to utilize it for heavy freight. It is estimated that owing to the slope of land and favorable character of the soil the work can be done in two years, at a cost of only 1,000,000.

The Bear Valley Reservoir.—The following is condensed from the San Bernardino Times, of October 16, 1884:

> A dam has been built at the head of Bear Creek for the purpose of converting Bear Valley into a reservoir for the storage of winter water.
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> The property was purchased for $22,500; in addition to this 700 acres of Government and railroad land were purchased, making 4,000 acres in all, and giving control of the whole valley.
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> The stock was divided into thirty-six parts, and the company was a partnership affair. It was incorporated with 3,600 shares, each representing 1 inch of water. Work was begun on the dam on September 27, 1883, and continued until November 17, at which time 250 yards of masonry had been put in place. On July 3, 1884, work was resumed with a large force of hands, and the dam has rapidly assumed shape and size, and by the 1st of December will be completed. The dam is very favorably located at the outlet of Bear Valley into Bear Creek, which empties into the Santa Ana, about 5 miles below. The valley is surrounded by mountains and has no other outlet but this, which here is very narrow, with precipitous rocky sides. Into the solid rocks of this gorge the dam is abutted, and is built in a curve arching inward, forming the arc of a circle, with a diameter of 335 feet. Its dimensions are on the top 390 feet from abutments, 60 feet from the bed-rock of the creek in the highest point, and conforming to the mountain slope on either side. The foundation is 17 feet in width, running up to 3 feet on the top, which is covered with huge blocks for coping.
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> The whole is built of vast granite blocks, which are quarried near the margin of the lake, and floated to the wall on scows, while a derrick built on a floating raft takes them and places them in position. The best quality of Portland cement is used for laying them, and all the interstices are filled with beton, which is thoroughly tamped into place, until the whole structure is one homogeneous mass. There are 3,304 yards of rock-work, on which 1,300 barrels of cement have been used. The cement is the most expensive portion of the work, being hauled over the rough mountain roads from Colton. The freight on it alone from Colton costs more than its purchase-price and freight from England to Colton.
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> Beneath the dam is a stone culvert for the outlet. This is closed by a gate 21 by 24 inches, capable of discharging 8,000 inches of water, which runs into a weir, where the flow can be measured in inches. This gate and weir regulate the flow of water. On one side of the dam a channel over solid rock is provided for the overflow of the surplus water. This is some 4 feet lower than the top of the dam, and affords ample discharge for the superabundant water.
>
> The lake formed by the dam will extend back into Bear Valley over 5 miles, with an average width of nearly a mile, and a depth of 12 feet, and will contain the enormous amount of 8,000,000,000 gallons. To supply this the valley furnishes over 60 square miles of drainage area, on which falls three times the amount of water the valley itself receives. The rainfall for Bear Valley this season was over 100[*] inches, and the probable average will be over 35 inches per season. All the rain that falls over this area finds its way into the lake. The stratifications of the mountains all trend toward the valley, and seepage is impossible, while the highest temperature this past summer was 84, and the average for the hottest part of the day 76 degrees. Under these conditions evaporation is reduced to a minimum, and all the winter precipitation will be saved for summer use.
>
> The lake covers 2,000 acres of land with its depth of 12 feet, and from it can be drawn during the summer months, for irrigating, for 100 days and nights, a continuous stream of 6,000 inches without even then exhausting the supply. It is not proposed, however, to draw off more than 3,600 inches, the balance being left for a reserve in case of a drought, when it may be needed. To give some idea of what these 3,600 inches can accomplish, it is only necessary to know that it is more water than was furnished during the season of 1883 by all the streams of the county combined, of which the following is an estimate: Santa Ana, 650; Mill Creek, 400; Riverside Canal,

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[*] Rainfall in San Bernardino Valley below, for the same season, about 38¼ inches. Rainfall in season of 1884-'85, Bear Valley, 20 inches; San Bernardino Valley, 10 inches.

1,000; Lytle Creek, 300; Etiwanda, 200; Ontario, 200; total, 2,750. This estimate is on the basis of a dry season.

Thus it will be seen that Bear Valley, with its 3,600 inches, will make possible the doubling of the arable land of San Bernardino Valley, and the doubling or even trebling of the population and the increase of wealth which population brings.

In the construction of this work Mr. Brown, the engineer, has exhibited a vast amount of enterprise, labor, and skill. To ascertain the amount of water actually flowing into the Santa Ana River and Bear Creek, last year, in September, simultaneous measurements were taken at eight stations every hour, day and night, for three days. All of these were kept and recorded for future use, in order to allow the owners of this water all that they are entitled to, the company claiming only what they save during the winter months. To facilitate the work a natural earth dam across the valley confined the waters of last winter; and when the dam had reached a sufficient height to warrant it, some of this water from the upper lake was discharged into the lower one, and scows, rafts, and boats were built for hauling stone and sand and other material, which saved an enormous expense in teaming. Work shops, boarding houses, sleeping apartments, &c., were erected for the men, and everything that would facilitate the work and at the same time reduce the cost was provided.

The cost of the dam proper will not exceed $50,000, and the whole property not over $75,000, the whole owned by our citizens, and mostly by land owners who will use their water on their own lands. Considering what this work will do, the outlay is very small.

The company have now under consideration the construction of a flume from Bear Valley to this (San Bernardino) valley. They have acquired a vast body of most excellent timber, which by means of a flume, not costing over $30,000, can be laid down here in the shape of lumber and firewood at much less than the present cost of those articles. Should additional storage room ever be required the present dam could be enlarged and raised some 40 feet higher, without great additional cost, and the storage capacity thus increased four-fold.

PRACTICAL RESULTS OF IRRIGATION.

The Department desiring practical information, showing what has been or is being accomplished in the matter of irrigation and its effect in the way of reclamation, production, climatic changes, or other results, addressed inquiries to all persons known or understood to be acquainted with or interested in the subject matter of this investigation. In addition to a large number of personal letters, several circulars were printed and hundreds of copies were sent to land owners, colonists, farmers, engineers, editors, and other persons within the States of California, Colorado, Kansas, Nevada, Texas, and Oregon, and also in the Territories of Wyoming, New Mexico, Montana, Utah, Idaho, and Arizona, as well as to authorities in Mexico. The results of these inquiries are embodied in the following carefully collated replies:

CALIFORNIA.

(1) *Give location, geographical and postal, of your colony or enterprise, area thereof, past and present, and any facts bearing thereon; also size of colony, farms, and ranches.*

George B. Otis, Selma, Fresno County, writes as follows:

Selma is not a colony, but a central point or town, built up by independent irrigation canals and individual irrigators.

The water supply is entirely free from any monopoly control, being in the hands of a joint-stock corporation, the stock of which is owned principally by settlers. The area contributory is about 10 miles east, 5 miles south, 12 miles west, and 5 miles north. It is 15 miles southeast from Fresno City, the county seat of Fresno County. Geographically, it is near the center of the delta of King's River, and midway of the great San Joaquin Valley.

From Fresno, Frank Dacy writes:

Township, 15 south, of range 22 east, 36 sections, occupied by me in 1870 as a sheep range, and was to all appearance a barren waste. Four years later land was selling at $2.50 per acre.

In 1875 a small irrigating ditch from King's River made the soil produce beyond all expectation; result, all the Government lands were taken by settlers. In 1880 we brought in the Fowler Switch Canal, 40 feet on the bottom, 60 feet on top, 5 feet deep, and 28 miles long, terminating at section 36, in township 15 south, of 20 east, Mount Drohlo base and meridian.

From Fresno, Cory, Braley & Harvey, agents for Washington Irrigation Colony, write:

Washington Irrigation Colony is situated 4 miles south of the town of Fresno, county of Fresno. The colony contains 7,000 acres, laid out in avenues. Each farm contains 20 acres, and has a large supply ditch, which carries the water to the highest point on the land.

From Fresno, Col. W. H. Ingels, secretary Fresno Canal and Irrigating Company, writes:

Our canals are situated in Fresno County, California; post-office address, Fresno City, Cal. The section is largely arranged on the colony plan, being divided into 10 and 20-acre lots, although we have a great many larger tracts of, say, from 160 to 400 acres in vineyards, orchards, &c.

From J. W. North, manager Washington Irrigating Colony, Fresno, Cal., the following reply came:

The Washington Irrigating Colony is located southeast of Fresno City, Cal., and is 5 miles distant from that town. It has two post-offices, Easton and Oleander. It contains 7,040 acres, and is settled in small farms of from 20 to 80 acres. Fruit and grape culture the chief business.

P. Y. Baker, originator of the '76 canal enterprise, writes:

It is in Fresno and Tulare Counties. Post-office is Traver, Cal. Area, 200,000 acres. Colony lots contain from 10 to 40 acres. They are gradually changing from cereals to fruit and alfalfa pasturage.

There are 3,000 acres, divided into colony lots.

Louis Walker, superintendent Moore Ditch Company, writes from Yolo County as follows:

This ditch was dug in the year 1856 by James Moore, and has been in use ever since for irrigating purposes. It is used during the summer months for irrigating vineyards, fruit trees, alfalfa, &c.; post-office address, Woodland, Yolo County, California.

From Banning, San Bernardino County, a correspondent writes:

Location, Banning, San Bernardino County, California; post-office, Banning; area, 6,000 acres, cut up into plats of 2½, 5, and 10 acres; blocks for sale.

H. Baecht writes from Olivenheim, Encinitos, San Bernardino County, as follows:

The colony of Olivenheim consists of 450 acres of land situated in the valley of the San Elijo Creek, about 3 miles from its mouth, and forming a part of the Encinitos Grant. The land was originally divided into 5-acre blocks.

From Lugonia, San Bernardino County, a correspondent writes:

Lugonia is located 8 miles southeast of San Bernardino, the county seat of that county, at the eastern terminus of the valley of the same name, and near the headwaters of the Santa Ana River and Mill Creek, where they debouch into the valley which extends to the Pacific Ocean, a distance of 60 miles. The local names given the four settlements adjoining are: Crafton, Brookside, Lugonia, and Redlands. They are distant from the depot on Southern Pacific Railroad from 2 to 5 miles, and are all supplied with daily mail and telephone. The valley at this point has a width of about 6 miles, and an elevation of about 2,000 feet above sea level. The age of these settlement varies from five to twenty years. The lands are mostly subdivided and for sale in small tracts.

From Tulare County, Elias Jacobs writes in reply:

Within 15 miles east of Visalia the waters of the Kaweah have been so utilized as to form a cluster of colonies, extending westerly to the banks of King's River. The main streams are utilized as carriers. Branches of canals wind their way along the high ridges, thus supplying the farms and colonies. In size they range from 20 to 400 acres.

S. F. Earl, secretary of the '76 Land and Water Company, Traver, Tulare County, writes:

This is about the center of California. The post-offices are at Traver and Centerville, 25 miles north and south, by 12 miles east and west. The colony lots are from 5 to 20 acres each. Farms are from 40 acres to several sections, mostly in 160-acre tracts.

S. E. Biddle, Hanford, Tulare County, writes as follows:

The Mussel Slough irrigation district is situated in the northwestern portion of Tulare County.

C. I. Hopkins, Pasadena, Los Angeles County, replies as follows:

The settlement of Pasadena includes in all about 4,500 acres. It is situated on a mesa or bench at the southern foot of the Sierra Madre Mountains, at the western end and terminal of the San Gabriel Valley. Its post-office is Pasadena, Los Angeles County. It is cut up into small holdings from half an acre to 80 acres each, the great majority being 5 and 10 acre lots. Elevation from 800 to 1,500 feet above tide water. It is all irrigated by mountain water conveyed in many miles of wrought-iron pipes, from 10 inches to 1 inch in diameter. All its agriculture depends on irrigation, except grapes, and grain or hay crops.

Richard Melrose, Secretary Anaheim Union Water Company, writes:

Anaheim is in Los Angeles County. Irrigation began in 1858. Area of territory then irrigated 1,200 acres. Now district comprises 12,000 acres; actual area irrigated, 7,000 acres

Messrs. Judson & Brown, Redlands, San Bernardino County, in reply, sends maps, and says:

Redlands is in San Bernardino County. It contains 2,500 acres. The average size of farms is 12½ acres. The altitude, 1,500 feet, It is distant from the Pacific Ocean 70 miles. Sea breezes prevail in summer, with a mountain wind from the east at night. Frost not severe enough to injure young orange trees. No noxious insects. The projectors of the Redlands Colony owned 2,500 acres, but there are 3,500 more contiguous, making 6,000 acres in all.

H. Y. Stanley, secretary Arroyo Grande Water Company, San Luis Obispo, replies as follows:

The Arroyo Grande Water Company is the name of our small company, and the lands irrigated are located in the Valley of Arroyo Grande, San Luis Obispo County. Longitude, about 119° west; latitude, about 35° 20′ north. Our post-office address is Arroyo Grande. A portion only of the valley is covered by the ditches of the company. The ranches vary from 1 acre to 60 acres. The company has been in existence three years.

A. G. Adams, National City post-office, San Diego Bay, replies as follows:

Our post-office is National City. Our enterprise is the Rancho de la Nacion, or National Ranche, situated on the east shore of San Diego Bay, beginning at a point north of midway of the bay and extending southward to a point near the head of the bay. Rancho is not strictly a colony. It occupies 42 square miles. Has now a population of about twenty-five hundred people, located mostly on small ranches of from 5 to 20 acres.

(2) *Original value of land per acre; present selling price; state whether the purchase of land carries water also; if not, give rent or price of latter per acre.*

From Banning, San Bernardino County, a correspondent replies:

The original value was from $2.50 to $50 per acre. The selling price for land and water delivered on each lot is now $150 per acre. Water at rate of 1 inch to each 6 acres.

Messrs. Judson & Brown, Redlands, San Bernardino County, write:

The original cost was from $2.50 to $25, without water. Present selling price is from $100 to $200 per acre, with water.

From Lugonia, San Bernardino County, a correspondent writes:

The lands of this location in 1873 were sold from Government prices up to $6 per acre. The present selling price, with water, is from $100 to $200 per acre, depending upon location and quantity sold in one body.

H. Baecht, Olivenheim, Encinitos, writes:

The land was purchased by the colony for $15 per acre. It is now held at $40. There is abundance of water in the valley, but no system of irrigation has yet been adopted.

George B. Otis, Selma, Fresno County:

In 1877 the lands were considered worthless, or fit only for roving bands of stock. Irrigated land in 1886 is worth from $30 to $75 per acre. Land and water are purchasable separately. The water rental varies, and is constantly decreasing. It is less used for irrigating year after year.

J. W. North, manager Washington Irrigating Colony, Fresno County, says:

The original value of land was $5 per acre; the present price, unimproved, is $50 per acre. The purchase of land carries water also, except that there is an annual water-tax of 62½ cents per acre.

A. G. Adams, National City post-office, San Diego Bay, replies:

Original value of first purchase was about $3 per acre. Land now brings from $15 to $500 per acre, according to location. The average price is about $100 per acre. Every purchaser has complete and independent control of his own water privileges.

H. Y. Stanley, secretary Arroyo Grande Water Company, San Luis Obispo County, replies:

Land, at the time of the formation of this company, was selling at about $100 per acre. The water stock belongs to the land, and sale of land carries with it the stock.

C. V. Hopkins, Pasadena, Los Angeles County, replies as follows:

The original price, ten years ago, was from $8 to $13 per acre. The present selling price, according to location and improvements, from $150 to $2,000 per acre. Purchases of land always include water rights, as no water can be obtained from wells, or by boring. No water rented.

Richard Melrose, secretary Anaheim Union Water Company, writes:

In 1858 land sold at $2 per acre, in 1886 at from $100 to $150 per acre, including water stock, one share to the acre.

S. E. Biddle, Harford, Tulare County, replies:

The original value of the land was not to exceed $2.50 per acre, and it ranges now from $20 to $100. Water rights generally go with the sale of the land; otherwise the cost per acre for irrigation does not exceed $1.

S. F. Earl, secretary '76 Land and Water Company, Traver, Tulare County, says:

Original value of land from $1.25 to $50 per acre. All land owned by the '76 Land and Water Company, and many outside lands, are covered with water rights.

Elias Jacobs, Tulare County, writes in reply:

Land is worth from $2 to $5 per acre; after irrigation, from $15 to $100, exclusive of water, which is obtained at a rental ranging from $1 to $1.50 per acre. The season governs the value of the water.

P. Y. Butler, originator '76 Land and Water Company, writes from Traver, Tulare County:

When the canal was started land sold at an average of $3.50 per acre; that was in the spring of 1882. The same land now averages about $20 per acre.

The purchase of land carries water with it. The annual assessment on the same is 50 cents per acre.

Lewis Walker, superintendent Moore Ditch Company, Yolo County, replies to the above:

Land from 1856 to 1865 would not exceed from $5 to $7 per acre, and no sale for it at that, in money. All land that is now reached by this ditch will readily bring from $100 to $150, much of it still higher, even with no improvements. The finest grape and fruit land in the world lies in this belt. This is without water right, as the water right is private property.

Cory, Braley & Harvey, agents Washington Irrigating Colony, Fresno, say:

Before the water was brought to it the land sold at $5 per acre. Present price is $30 per acre.

W. H. Ingels, secretary Fresno Canal and Irrigating Company, Fresno, says:

Before water was brought to it the land was considered worthless, and was sold at $1.10 per acre. Now irrigated portions sell at about $30 to $50. If water is bought and located on land it is then transferable with it. Our canal rents no water, though the canals lower down on the river rent it at about 50 cents an acre per annum.

Frank Dacy, Fresno, writes:

Government price, $1.25 per acre. It now sells from $15 to $50, according to soil and location. The rent is about $2 per acre, without, and $4 with water.

(3) *Products of land; amount market and average value of crops; how long planted. Are fruits grown?*

From Banning, San Bernardino County, comes this reply:

Nothing yet bearing to amount to much, as the colony is only one and a half years old.

From Judson & Brown, Redlands, San Bernardino County:

Oranges, lemons, grapes (raisin), peaches, apricots, pears, &c. Barley on land that awaits water, to be devoted in future to fruits. Fruits planted from one to four years; colony organized November, 1881, and first planting made in 1882. Too young to make mention of crops, although orange trees are just beginning to bear.

From Lugonia, San Bernardino County, a correspondent writes:

The products of the land embrace all varieties of vegetables, grain, and alfalfa (Chilian clover), all varieties of deciduous fruit, and nearly all the varieties of citrous fruit; also the wine and raisin grape, and the olive. The average value of the deciduous fruit crop per acre in full bearing is $100. The raisin grape and the orange often exceed this amount by one-half.

The above returns are based upon actual sales for a term of years. The sale of orchard products is usually made to local dealers, to whom the fruit is delivered in the orchard or at the railroad depot.

H. Baecht, Olivenheim, Encinitos Colony, San Bernandino County, writes:

This colony has been in existence for only part of a year.

George B. Otis, Selma, Fresno County, says:

Everything semi-tropical or temperate, fruits, grains, nuts, roots, vines, figs. Too much liability of frost to raise oranges, limes, or lemons. The wheat acreage and product are constantly increasing, and quality of grain grown is better for milling. Irrigation is moistening the air and softening the flinty nature of the grain.

I. W. North, manager of the Washington Irrigating Colony, Fresno County, writes:

Fruit and vines; average value of fruit and grape crop from $50 to $100 per acre.

Cory, Braley & Harvey, agents of the Washington Irrigating Colony, Fresno County, send the following:

Raisin vines planted from one to six years. Five year old vines yield one and a-half tons of raisins, which sell for $200 a ton. Fruits are grown to great perfection.

Frank Dacy, Fresno, California, writes as follows:

Wheat, barley, and Egyptian corn are grown. The present value of wheat and barley is 1¼ cents per pound. Corn is $1.25 per 100 pounds. Wheat and barley will average about 20 bushels per acre, and corn about 40 bushels.

All fruits are grown in large quantities. The sweet potato, yam, and watermelon grow prolifically. Our raisin and wine grape cannot be surpassed.

A. G. Adams, National City, San Diego Bay, says:

The products cover a long list of grain and fruits, but the most successful is the fruit and vegetable crop. This includes all the vegetables, the orange, lemon, lime, and other citrous fruits, the olive, the fig, all varieties of grapes, and the peach, apricot, prune, and apple.

H. Y. Stanley, secretary of Arroyo Grande Water Company, San Luis Obispo, replies:

The principal product of this valley is beans, which vary in amount per acre from 1,500 to 5,500 pounds, according to season and locality. The price is from $1.25 to $3.50 per cental in different years.

All kinds of fruits, including semi-tropical, grow well, especially small fruits. Our vegetables of all descriptions cannot be excelled anywhere. The bean crop is planted in April and May, and harvested in September and October. It is not irrigated after being planted.

O. T. Hopkins, Pasadena, Los Angeles County, writes as follows:

Oranges, lemons, limes, grapes, grain, hay, apples, peaches, apricots, all kinds of deciduous and citrous fruits.

The oldest plantations are not more than ten years old; consequently no plantations are yet in full bearing, and "market and average value of crops" cannot be stated. In a few years more we expect to realize from $50 to $100 per acre from grapes, and from $100 to $300 per acre from citrous fruits and deciduous orchards.

Richard Melrose, secretary Anaheim Union Water Company, writes:

Irrigable lands are used mostly for the production of wine and raisin grapes, oranges and lemons. Some of the vine area was planted in 1858. The bulk of the vines and trees has been planted within the past ten years.

S. E. Biddle, Hanford, Tulare County, writes in reply:

Grain, potatoes, fruit, and hay, principally grown from alfalfa (Lucerne). The products in every thing are unequalled. Raisins are so far the most profitable in the fruit line. Hay fed to stock stands next; in fact, all products pay very handsomely.

Elias Jacobs, Tulare County, writes:

Grain of every description; of grasses, alfalfa chiefly. The value of crops of every description for the year 1885 was upwards of $1,000,000. Fruits are of eight years growth; grain some ten or twelve years.

P. Y. Baker, originator '76 Land and Water Company, writes from Traver, Tulare County:

Wheat, oats, barley, Indian corn and dura, beans, potatoes, rye, alfalfa, all kinds of fruit, including citrous fruits. The raisin and wine grapes attain the greatest perfection here. Most fruits are just coming into bearing. Our grain products for the coming harvest are estimated to be about 2,000,000 centals, valued at about $3,000,000.

Lewis Walker, superintendent of the Moore Ditch Company, Woodland, Yolo County, writes:

Grain of all kinds, except, perhaps, corn, is grown in abundance. Wheat produces as high as 40 bushels per acre; an average crop is about 30 bushels. Alfalfa is the most profitable, as three crops of hay can be taken from the land in one summer, when it has been properly irrigated once or twice during the season. The finest grapes for raisin making are grown here, and the land is becoming so valuable for fruits and vineyards that each year large tracts are set in vines, almonds, figs, apricots, and peaches.

(4) *Extent of irrigation works and their character, source of supply, method of distribution' cost and value of irrigation works, amount available at present and prospectively, nature of works, service per acre, any general facts showing extent of works, land areas, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

From Banning, San Bernardino County, California, comes the following:

There are 5 miles of stone and cement ditching, with flumes and open ditches for about 20 miles. The cost of irrigation works up to this date is $15,000. We are constantly carrying on the work. Available water is now 1,000 inches; prospective, 2,000 inches, distributed at the rate of 1 inch to six acres.

Messrs. Judson & Brown replied to No. 4 from Redlands, San Bernardino County, as follows:

The irrigating works consist of a reservoir, covering some 20 acres of ground, and about 12 miles of cement pipe for distributing the water, with small reservoirs scattered over the tract, for dividing the same and sending it down the different lines of pipe. Water is taken from the main reservoir by means of iron discharge pipes, with valves. There are, in addition to the above, some 7 miles of stone-paved and cemented ditches to conduct water from the mountain cañons to the main reservoir. The colony has also a leading interest in the Bear Valley Reservoir.

From Lugonia, San Bernardino County, a correspondent writes:

The irrigation works consist of four canals or zanjas, of from 6 to 10 miles in length, a portion of which is rock-lined and cemented. The source of the water supply is the Sierra Range of mountains, designated at this point as the San Bernardino. The method of distributing the water is by turns, or in rotation, or by the inch. The cost of the works will aggregate $50,000. The amount of water available at present is about 3,000 inches prospectively, and by reservoiring treble this amount, or an almost unlimited supply, can be obtained. A reservoir of 1,000 acres is already being utilized.

Frank Dacy, Fresno County, replies:

We have three large canals between Big Dry Creek and King's River. All the supply is drawn from King's River. The Fowler Switch and Kingsbury Canal is owned by the farmers. Each man has the water turned by the superintendent at any point. The other canal is a speculative affair, and charges $100 for annual rent, and renters have no control of management.

Cory, Braly & Harvey, Fresno, Washington Colony, write:

The water for the ditches comes from the snow-sheds of the Sierra Nevada Mountains. It is tapped at the mouth of King's River, and conducted a distance of 20 miles to the Washington Colony. These ditches are abundantly supplied with water available for the country through which they pass.

George B. Otis, Selma, Fresno County, writes:

The Fowler Switch Canal, and the C. and K. Main Canals, 18 miles for the latter, and 24 miles for the former, with lateral branches, side-ditches, and waste-ways, will aggregate 100 miles each. The Fowler Switch Canal cost $90,000. C. and K. Canals cost $40,000.

I. W. North, manager of the Washington Irrigating Colony, Fresno, writes:

All the land of the colony is irrigable, and all has a water right. The proprietor of the colony constructed the canals, and purchased from the Fresno Canal and Irrigating Company water rights for the whole colony at $5 per acre. The canal cost $36,000. The water is brought from King's River, more than 20 miles. The water right is estimated at 1 cubic foot per second for 160 acres, and it is sufficient.

S. F. Earl, secretary '76 Land and Water Company, Traver, Tulare County, writes:

There are 23 miles in a 100-foot canal, 14 miles in a 60-foot canal, 10 miles in a 20-foot canal, and 40 miles in a 10-foot canal, and many lateral ditches. There are about 20 miles of a 20-foot ditch in course of construction. There have been about $250,000 expended.

Lewis Walker, superintendent Moore Ditch Company, Woodland, Yolo County, writes:

The water used for the supply of the above ditch is taken from Cache Creek, a fine stream of water which heads at Clear Lake, in the Coast Range of mountains, running east, and emptying into the Sacramento River. The cost of the dam on this stream was about $25,000, while the ditches and branches probably cost $50,000. It costs from $2 to $3 per acre to irrigate land. All land accessible to this ditch is in cultivation, none being used for cattle or sheep.

Richard Melrose, secretary Anaheim Union Water Company, Los Angeles County, writes:

The Anaheim Union Water Company has 25 miles of main canals and 60 miles of branch ditches. Cost over a quarter million dollars, but could be replaced for $126,000. It is supplied from Santa Ana River, distributed through branch ditches to lands of irrigators from 4,000 inches in winter to 500 inches in summer; service per acre varies very considerably with character of soil; semi-sandy soil will take 100 inches to the acre for a half hour; stiff soil half that quantity.

C. I. Hopkins, Pasadena, Los Angeles County, writes:

No irrigated land is used for cattle or sheep. The source of supply is in the Arroyo Seco. The water is brought in a cement ditch, 3 miles long, terminating in a reservoir, and is thence distributed in iron pipes. Other works bring water from mountain cañons, where every drop is utilized by tunnels, &c. Water stock is owned by several corporations, geographically segregated, and water is distributed to stock owned and in proportion to land owned. One hundred and fifty thousand dollars have been so far spent, and the sum is annually increased as population demands. Water is invaluable. It is worth, when impounded in suitable works, $1,000 per square inch in a section flowing without pressure.

H. Y. Stanley, secretary Arroyo Grande Water Company, San Luis Obispo, writes:

Our ditches are 10 miles in length; some are flumed. There are two dams in the Arroyo Grande Creek. One reservoir covers some 2 acres of land. The cost has not exceeded $4,000, and covers 2,000 acres of land that could be irrigated.

A. G. Adams, National City, San Diego Bay, writes:

That portion given to sheep, cattle, &c., is dependent on winter rains; except in the valleys adapted to alfalfa and evergreen millet. Irrigation is carried on entirely by means of wells, with the aid of wind-mills; the regular sea breezes make this a safe and practicable process. It is distributed by means of pipes and ditches, from reservoirs constructed for the convenience of the farm. The nature of the soil is such that fruit trees need but little water during the dry seasons.

(5) *Climatic conditions, temperature, and rainfall; results of observations, if any, as to the influence of irrigation or moisture of the earth or sky; effects of irrigation on health, fertility of soil, &c.:*

A. G. Adams, National City, San Diego Bay, writes:

No perceptible change in the climate, as regards rainfall, has been brought about by irrigation. Annexed is a table embracing the Signal Service observations. Table showing inches of rainfall on San Diego Bay during each rainy season (October to March, inclusive), from 1871 to 1882, inclusive:

Months.	1871 and 1872.	1872 and 1873.	1873 and 1874.	1874 and 1875.	1875 and 1876.	1876 and 1877.	1877 and 1878.	1878 and 1879.	1879 and 1880.	1880 and 1881.	1881 and 1882.
October	.05	......	......	.53	......	.08	.81	.96	.39	.53	.24
November	1.19	......	.77	.88	2.25	.04	.06	......	2.77	.28	.12
December	1.39	1.44	5.46	.55	.41	.15	3.89	1.57	6.32	4.15	.30
January	.99	.44	3.11	2.38	2.47	1.05	1.45	3.54	.61	.52	4.53
February	1.63	4.15	3.73	.37	2.44	.18	4.83	1.04	1.50	.45	2.55
March	.46	.11	1.20	.45	1.78	1.44	1.41	.10	1.43	1.88	1.02
Totals for rainy seasons	5.71	6.14	14.27	5.16	9.35	2.94	12.43	7.21	13.02	7.81	8.76

To which may be appended for 1883: Rainfall, 4.56; for 1884, "28"; 1885–'86, 6.68.

Our process of irrigation is cheaper than any other, and is adapted to small farms. Our ranche is, to a great extent, owned by a company organized from stockholders of the Atchison, Topeka and Santa Fé Railroad. They have not organized any system of irrigation. An artesian well is being sunk; it is now down 600 feet. Other experiments are being tried.

H. Y. Stanley, secretary Arroyo Grande Water Company, San Luis Obispo, writes:

As to the climate, the temperature is even; in some winters there is no frost. Summers are cool and pleasant. Late in summer and fall it is foggy. Average rainfall 17 inches. We don't irrigate for crops more than one year in three, and then before planting. The water is hard and is not considered very good for the soil. The evaporation is not rapid, and if the surface is cultivated, the health of the community is not affected by the amount of water used.

From Banning, San Bernardino County, a correspondent writes:

Conditions are good; temperature 34° to 120°. The average precipitation for ten years is 11 inches per annum, and drainage is good; consequently it is very healthy here. Region is especially recommended for all bronchial troubles.

C. T. Hopkins, Pasadena, Los Angeles County, writes:

We have rains varying from 7 to 54 inches annually between December and March. The average temperature 52°; lowest, 32°, resulting in a few white frosts in wet season. The highest 110°. Probably thirty hot days in a year; six to ten days at a time in March, August, and September. We have no shallow stagnant water and no malaria.

Richard Melrose, secretary Anaheim Union Water Company, writes:

Temperature is mild in winter, and not unpleasantly warm in summer. Rainfall very uncertain, but not much needed. An average of 9 inches would insure good cereal crops. Irrigation has no effect on moisture of the earth or sky. It has no unhealthy effects, as the soil that requires irrigation here has perfect drainage. It increases the fertility of the soil, and winter water is used less for the moisture than for the fertilizing mud it contains.

S. E. Biddle, from Hanford, Tulare County, writes:

The climatic conditions are improved in summer, being cooler. We think the rainfall has been increased by irrigation. There are no perceptible changes in the health so far, *i. e.*, within ten to twelve years. Alkaline matter seems to have been forced to the surface by irrigation in a small portion of the district, but not enough to cause any alarm yet; there is some doubt about this matter in the future.

S. F. Earl, secretary '76 Land and Water Company, Traver, Tulare County, writes:

Temperature from 20° above zero, to 110° above zero. Rainfall from 9 to 16 inches. Observations: The more we irrigate the greater the rainfall. The water from the mountains is a great fertilizer.

P. Y. Baker, '76 Land and Water Company, Traver, Tulare County, writes:

Summer warm and dry; cool nights; winters cool, occasionally light frosts. Temperature as low sometimes as 20° but not often; maximum in summer, 85°. Irrigation has doubled the annual rainfall. No injurious effects to health, as we have good drainage. Fertility increased productiveness four-fold.

Lewis Walker, superintendent Moore Ditch Company, Woodland, Yolo County, writes:

The annual rainfall, which all, or nearly all, occurs between November and April, is from 12 inches in a dry year to 18 and 20 in wet seasons. So far as I know the irrigation in the section embraced above does not affect the health of the people; still I have heard complaint in other sections of the State where irrigation is carried on that it produced fever and ague. The hotest weather in summer is 100° in this locality, and the coolest in the winter is 28° to 30°. Of course the above are the extremes, and only last a few days at a time.

I. W. North, manager Washington Irrigating Colony, Fresno, writes:

Climate mild; extreme heat 110°; extreme cold 25°. In exceptional years the thermometer has indicated as high as 115°. No bad effects on health from irrigation except from neglect. Fertility increased. The land below surface fills up with water gradually, being now only 8 feet down where it used to be 50. Irrigation is stopped when water is only 8 feet from surface. Rainfall from 9 to 20 inches. Moisture of atmosphere is increased by irrigation.

George B. Otis, Selma, Fresno County:

Warm, warmer; hot, hotter; sometimes to 110°, and yet not a debilitating heat, dry, and therefore not exhausting like moist heat. No sunstroke; rainfall, variable; less rain, more canal work; greater independence from possible droughts; no failure of crops on irrigated land. Fertility of soil is increasing; absorbent in its character, the sand becomes a rich vegetable mold.

Cory, Braley & Harvey, agents for Washington Irrigating Colony, say:

Climate semi tropical; health good with due care. Malaria unknown. Ditches carry water to every 20-acre lot by process of subirrigation, which renders surface irrigation unnecessary and undesirable.

W. A. Ingels, secretary Fresno Canal Irrigating Company, says:

Formerly very dry; since irrigation, and since trees have grown, rain falls more plentifully. Temperature, from 28° in winter to 115° in summer, though these points are rarely reached. New lands, when irrigated, have a tendency to cause chills and fever, but not to any great extent.

Frank Dacy, Fresno, writes:

Temperature in winter, lowest 24°, average 30°; in summer, highest 108°. Rainfall from 4 to 26 inches. The earth is filling up and low depressions are forming. The water at my place has risen 28 feet. The effect on health is to produce fever and ague in some localities.

General notes.—Frank Dacy, from Fresno, states cost of canals and other irrigating excavations, &c., to be $160,000, and in addition to the Fowler Ditch there are other private ditches leading from the main ditch, the whole cost of which would be probably $150,000, making a total of $310,000.

Judge J. W. North, manager Washington Irrigating Colony, Fresno County, writes:

This county is in the great San Joaquin Valley, and has over 2,000,000 acres valley land, nearly all irrigable. Without irrigation it rents for pasturage at 10 cents per acre. In fruits and vines it often produces more than $100 per acre.

All the land of the colony is irrigable, and all has a water right. The land proprietor constructed the irrigating canals on the colony, and purchased from the Fresno Canal and Irrigation Company a water right for the entire colony at $5 per acre. The construction of the irrigating canals in the colony cost about $36,000.

The water is brought by the Fresno Canal and Irrigation Company from King's River—more than 20 miles—to the colony. The water right is estimated at 1 cubic foot per second for 160 acres. It is sufficient. Climate is mild; extreme heat in summer, 110° F.; extreme of cold in winter, 25° F. In exceptional years it has been 115° of heat and 15° below the freezing point in winter. Other years it has only been down to 27° in winter. No bad effects on health from irrigation, except from neglect in keeping standing water.

Fertility increased by irrigation. Rainfall from 9 to 20 inches. Moisture of atmosphere perceptibly increased by irrigation. The land below the surface fills up with water gradually, so that it is now only 8 or 10 feet down to water, where it used to be 50. Irrigation is stopped when water is only 8 feet from surface.

This, Fresno County, is in the great San Joaquin Valley, and has over 2,000,000 of acres of valley land, nearly all irrigable. Without irrigation it rents for pasturage at 10 cents per acre. In vines and fruits it often produces more than $100 per acre. The English common law of riparian rights, that England has long since discarded in all her irrigable provinces, is still an incubus and nightmare upon our legislators and courts. That "Patch-work of fifteen centuries," as Jeremy Bentham called it, is like an English fog—to obscure the vision of our judges and lawyers—and so it has hampered the irrigation of this arid coast as the same common law hampered all our fresh-water navigation in the United States for fifty years. When our law-makers and courts shall become wise enough to make our laws synonymous with justice, and adapt them to our own time and our own country, then we may hope for more rapid development of these irrigable lands.

W. H. Ingels, secretary of the Fresno Canal and Irrigation Company, writes as follows:

Our water is taken from King's River, about 18 miles east from Fresno City, in a large ditch, with capacity to run about 1,000 cubic feet of water per second. From this large ditch it is taken by smaller ditches and distributed over the land.

Our canals cover a territory of about 600 square miles, although only a portion of that amount is irrigated. In time we think we can cover most of it, as the soil is fast filling up with water, and not near so much water is used as at first. Water is sold at the rate of $800 per 160 acres, with an annual payment of $100 in addition. Do not know what canals have cost, but they pay interest on about $250,000. This was formerly a very dry country, but since it has been irrigated, and many trees, &c., have grown, rain seems to fall more plentifully. Temperature from 28° in winter to 115° in summer, although these points are rarely reached. When new land is irrigated it has a tendency to cause chills and fever, though not to any extent. Soil very fertile.

The plan of irrigating the dry plains of Fresno County was conceived about fifteen years ago, Mr. M. J. Church, the present president of the Fresno Canal and Irrigation Company, who was one of the first promoters of the enterprise. At that time the plains were used only for pasture for cattle, sheep, &c., and amounted to but very little for that, as they were almost barren. Land could be had almost for the taking, while there was not a building where the thriving city of Fresno now stands. There are now from ten to fifteen large canals tapping King's River, although there has been almost endless litigation with the so-called riparian owners farther down the river. There has been a continual stream of immigration, which continues to the present time. During the winter and spring there is plenty of water in the river to supply all the canals, but during the latter part of the summer and fall the canals that have the prior appropriation are the only ones that get the water.

P. Y. Baker, of Fresno, the originator of the "76" canal enterprise in that region, writes of it as follows:

The '76 Land and Water Company was incorporated June 7, 1882, with capital for canal of $280,000, and 30,000 acres of land. We sell land on the installment plan, one-fourth down, balance in three years, at 8 per cent. interest. The canal is capable of serving a vast area of land in addition to our own. We sell water rights to outside parties for $5 per acre. These rights attach permanently to the land, and are assessable to the extent of 50 cents per acre per annum. This covers the cost of repairs and distribution. We have sold 4,000 acres and rented 21,000 acres. The enhancement of values, by reason of the building of the canal, has more than paid for the land and canals.

King's River, from which our water supply is obtained, rises in the high sierras, in the Mount Whitney Range (the highest in the United States), having its source in natural reservoirs, vast snow-banks, which remain through most of the summer months but melt as the summer advances, thus insuring abundance of water most needed. Settlers are rapidly developing our vast resources. Our population has increased from about 800 to over 3,000 in two years. We have a country under one system of canals broad enough to sustain 50,000 people in the raisin, wine, and general fruit business.

The '76 canal is 100 feet wide on bottom, side slopes 3 to 1, carries 4 feet deep; grade, 18 inches to the mile; with main canal and laterals it is about 200 miles long. We allow 1 inch per acre (miner's measure). The cost was $380,000. Our capacity is 180,560 miner's inches. About 10,000 acres have been irrigated, and the works are being extended rapidly to cover more.

The summer is warm and dry, with cool nights; the winters are cool, the thermometer occasionally (but not often) marking as low as 20° above zero.

The maximum in summer is 85°. Irrigation has nearly doubled the annual rainfall. There have been no injurious effects to health, as we have good drainage. The fertility has increased productiveness four fold.

Messrs. Cory, Braly, and Harvey, agents of the Washington Irrigation Colony, Fresno, write as follows:

The supply of water is abundant. The ditches which carry the water to every 20-acre lot, supply by the process of sub-irrigation sufficient moisture to render surface irrigation unnecessary and undesirable. Climate, semi-tropical; health good, with due care; malaria unknown. Before water was placed on the plains of Fresno by irrigating ditches the land for nine months in the year was a parched desert of no value. After six years we have a magnificent country abounding with trees and foliage. Farmers on 20-acre places are making from $100 to $200 per acre.

Elias Jacob writes from Tulare County:

The supply of water is ample to irrigate every acre, except the foot-hill lands, and they could be supplied if a system of works were adopted. Where land has been irrigated for five or six years, it no longer requires water. The soil has been entirely transformed. Owing to the peculiar character of soil the present imperfect system has proved adequate; but if a better system were adopted, one-third greater area could be reached with no greater quantity of water.

From Lugonia, San Bernardino County, a correspondent writes:

The fertility of the land is enhanced by the continued deposit of fertilizing matter, conveyed by water for irrigation, increasing its value largely over land not irrigated. The reservoir referred to in my reply to your question, contains 1,000 acres, and is located 17 miles above the head of a ditch on Santa Aña River. The development of water by the artesian wells is being extensively conducted, resulting in a large flow of water from subterranean channels, amounting to 200 inches to a well at a depth of 200 feet. This development is likely to raise a legal question as to the right appertaining to prior development.

Mr. N. M. Orr, secretary of board of trade, Stockon, writes as follows:

Excepting in unusually dry seasons good crops of grain can be raised throughout San Joaquin County. Therefore no general system of irrigation has been adopted, nor have any large canals or ditches been constructed for the purpose of conducting the water of the rivers out upon the plains for irrigation purposes. The water from the Calaveras River has been diverted during several dry seasons, and made to irrigate limited quantities of the adjacent land. While this county has no land so arid that crops cannot be raised in favorable seasons, the productive capacity of at least 300,000 acres of its land would be almost indefinitely increased by the adoption of a general system of irrigation. In the immediate vicinity of this city there are seven flowing artesian wells, the water of which is used for irrigation.

These wells range from 900 to 1,200 feet in depth, are generally 8 inches in diameter, and give a flow of water ranging from 10,000 to 20,000 gallons of water per hour. From 50 to 100 acres of land can be irrigated from each well, and it is thereby made capable of producing a great variety of crops.

SAN GABRIEL VALLEY.

Abbott Kenney, of Kanieboa, San Gabriel Valley, Los Angeles County, writes:

The San Gabriel Valley contains several considerable colony irrigation enterprises; others are being formed, and many independent water rights exist, or are used by three or four ranches in combination. The largest independent ranch is the "Santa Anita," with, say, 20,000 acres subject to irrigation. Few of the independent ranches contain less than 200 acres, and the sizes range from this up to several thousand acres. The colony of "Pasadena," contains about 2,000 acres; the "Alhambra" about 1,000, the "Duarte" about 2,000 acres, the Aynsa 2,200, and the "Sierra Madre" 1,000. In the San Gabriel Valley there are, including colonies and ranches, about 100,000 acres in irrigation. The original value of land was $3 to $15 per acre; present price, $100 to $400 per acre. A young orange-grove near Pasadena Centre recently sold for $2,000 per acre. There were no buildings on the land. There is no system of renting water here. It is bought with the land in all colonies in this valley. A great deal of the water brought to the lands in this valley is used on orange and lemon trees, vegetables, walnuts, and alfalfa. Water is distributed for domestic purposes, and gardens in many places where deciduous fruits, such as apricots and peaches are grown. These fruits give good returns without irrigation, as do grapes also. Alfalfa produces about ten crops a year in favorable locations, and averages five or six mowings of 1½ tons to each acre, with free irrigation. It is used for dairy cattle. Oranges and lemons, with good treatment and plenty of water, will give about 1½ or 2 car-loads to 10 acres, or, say, from 400 to 600 boxes, worth $1 per box on the tree. Grapes, when freely irrigated, will bear six and eight tons to the acre; without irrigation, on the dry lands, they produce from 1½ tons to 2½ tons, the latter being a large yield for dry vineyards. It is not the general custom to irrigate vineyards in this valley. In Fresno and San Bernardino Counties, where the climate is drier, water is considered a *sine qua non* for success with a vineyard. The rainfall here is more than in those counties. Even in different parts of this country great differences of climate exist. The rainfall in the San Gabriel Valley varies in different parts of the valley.

On my ranch the lowest rainfall recorded was 12 inches in one season—that is one rainy season, from October to May—and the lightest 60 inches, for the season of 1883-'84.

The average, I think, is about 18 or 20 inches for a season. No ill effects have yet resulted in this valley from irrigation. At least none that I know of. Malarial affections are generally thought to be the first to appear when irrigation affects the health. This has been the case in Fresno County, in this State. But here the only places affected by troubles of a malarial type are the cienegas, or damp lands, or bottoms of old lakes, swampy spots where springs burst out. There is but one narrow belt of this kind and but one spot of damp land, San Gabriel Valley. Along the belt of springs children have been troubled somewhat with croup, and diphtheria, and in the damp spot called El Monte some malarial troubles of a mild type have always been known.

They do not irrigate at the Monte on account of the dampness of the lands. The ranches were formerly all devoted to cattle or sheep, and were generally very large 3-league ranches, or not less than 15,000 acres. Some divisions are now very small, from 1 to 5 acres; but speaking generally the colonies subdivide into lots of from 10 to 40 acres.

The ranches commonly range from 200 to 2,000 acres, but a few very large ones remain.

The sources of water supply are springs and streams from the mountains. There are also a number of artesian wells on the plains, and water is obtained in some cases by tunneling into the mountains. From the larger streams the water is taken out and distributed in ditches, but this method is being given up as too wasteful. The greater number of water developments are taken out in pipes or flumes, and a few in cement ditches. There are great differences of opinion as to what water will do, but the best authorities speaking for this climate say that 1 miner inch, 4-inch pressure, should serve 10 acres devoted to irrigable products. Different crops and different locations and soils require different amounts of water. Alfalfa requires the most and orange next. Probably more water than the amount named could in most places be used with advantage on alfalfa. For oranges it is about right when they are planted in a proper soil, and with a proper exposure.

It is too soon to say anything definite about climatic changes. Other collateral matters are going on which must make any conclusions on this subject uncertain. For instance, the bush and timber lands on the steep mountains which surround us are being burned off and wasted to a frightful extent every year. An area of 60,000 acres is estimated to have been burned off last year on the Sierra Madre Range, between the Cajon and Soledad Passes. The result of this is already felt in the formation of destructive torrents that bring down sand and rocks into the valley and leave them in the fertile land destroying it.

The springs and streams are also diminished. If these causes go on we must anticipate a great reduction at an early date both in irrigation and in the tax-paying and productive power of this region. It is a very serious thing, indeed, this destruction of timber and undergrowth.

The mountain lands are worthless except to produce timber and as attractors and distributors of moisture. No one will look out for this property of the Government except it be the Government itself. No private property of so vast a value directly and collaterly would be thus left to itself and expected to take care of itself. Nor should the United States Government expect a miracle to take place in this matter. If the forest and bush lands, which are of such vital importance to this section, are to be protected, the Government, which is the owner, must attend to it. The mountains should be reserved permanently by the Government, to preserve the water sheds, and through them the tax-paying capacity of the people of this section, and these forests should be taken care of by resident agents.

WATER FACILITIES OF ANAHEIM.

The success of any portion of Southern California depends largely upon its water supply and facilities for irrigation, as the greater portion of the rains fall within a period of four months, and those crops which pay the best for the capital and labor invested in them require more moisture than results from these rains.

The Sierra Madre and San Bernardino Mountains rise to a great elevation on the east of this valley, and are of vast area. The rains fall heavily on this immense water shed and the highest peaks are snow capped the greater portion of the year. This water shed is drained by the Santa Aña River, which flows through this valley to the ocean.

It is the largest river in Southern California, heading 55 miles from here in the San Bernardino Mountain, one of the highest peaks of the Sierra Nevada range. From this point it wends its way through the San Bernardino Valley, a distance of 35 miles, to the Sierra Madre Range, and all the rivulets draining the eastern slope of this range empty into it and add to its volume.

It has worn its way through a defile of this range, and at the narrowest points the bedrock approaches very near the surface. This important physical fact causes the subterranean flow of water to rise to the surface and be made available for irrigation. By this wise provision of nature our water supply is secured from danger by the diversion of water for irrigation at settlements higher up the river which have to depend on the surface flow. The waters of the river are divided equally, the people of this section getting one half and the people of Orange and Santa Aña getting the other half.

Our water is conveyed to the settlement in two large canals, designated as the Cajon, and New Anaheim Canals. The Cajon, or upper canal, heads at a point near where the county line between this and San Bernardino County crosses the river. This is between three and four miles farther up the river than the head of any other canal that conveys water into this valley.

This canal is 10 feet wide in the bottom and 3 feet deep, and has a carrying capacity of 3,000 inches. It conveys water a distance of 16 miles, into North Anaheim, an elevated section of country at the base of the foot-hills. At the entrance of this canal into the settlement there is a small distributing reservoir that will hold the water during the night, doing away with the necessity for night irrigation.

This is a great saving of water and labor. The New Anaheim, or lower canal, has its source at a point on the river just below the head of the Orange Canal, between 4 and 5 miles below the head of the upper canal. This canal gathers up the waters that pass the upper canals, and gets the advantage of seepage of the river below them. It is 8 feet wide in the bottom, and 4 feet deep, with a carrying capacity of 300 inches, making a grand total of 6,000 inches.

It will be seen from the above that our irrigating facilities are very great, but we still have a large area of country not yet under cultivation, and knowing that with its development the demand for water will increase, and with a zeal and enterprise consistent with the importance of the water system as a component factor in the development of this country, the company are making arrangements to increase their water supply so as to insure all parties a sufficient amount to meet their requirements. In order to do this they have secured the site for a large reservoir on the upper side of the valley, at the terminus of the new Anaheim ditch, before referred to. This reservoir contains 47,161 acres, and will have a depth of 25 feet. When full of water its storage capacity will be 403,363,291 gallons, with a discharge of 10 cubic feet per second, or 75 gallons; it would take sixty days to empty the reservoir, supposing no water to enter meanwhile.

The reservoir will in all probability be completed within the ensuing year. The administration of our water affairs is on the best possible basis, the water company being of the people and for the people. It is a joint-stock association, known as the Anaheim Union Water Company, each share of stock representing an acre of land. A regular stockholders' meeting is held once a year, and a board of seven directors is selected from their number to manage the business of the company for the ensuing year. The charges for the water are no more than sufficient to cover the running expenses of the company.

In addition to the above source of water supply we have what is termed the artesian well belt, beginning about one mile west of Anaheim and extending westward to the ocean. Fine flowing wells are obtained at depths varying from 130 to 300 feet. A good well will furnish the water required to irrigate 40 acres of land. An inexhaustible supply of surface water can be obtained at all points through the valley at depths varying, according to locality, from 10 to 30 feet. The domestic water for the town of Anaheim is supplied by a well 9 inches in diameter and 90 feet deep. The water is pumped by a small steam pump in a tank holding 20,000 gallons, and thence distributed through pipes to all portions of the town.

THE SANTA AÑA VALLEY.

Mr. D. M. Baker, editor of the Santa Aña Standard, writes as follows:

Santa Aña is in Santa Aña Valley, Los Angeles County, California, 33 miles southeast of Los Angeles City; population 2,250; valley 16 by 30 miles in extent, with smooth, level land and rich soil. It was settled fifteen years ago and produces immense crops of oranges, lemons, limes, grapes, raisins, hay, corn, potatoes, and all products of the north temperate zone, and some tropics, except wheat and oats, for which it is too foggy near the sea shore, causing rust. Farms range in size from 5 to 40 acres, 10 acres being the usual size. It is situated in the great southern dry belt, and is very healthy. Stock ranches range from 160 to 50,000 acres in size. Good land originally worth $2.50 per acre, now, unimproved, worth from $1 to $2 per acre. Rent, $2.50 to $5. per acre; orchards much more. Land carries water with it in some water companies; in others it does not. In this town and part of the valley it carries it.

In Anaheim, 7 miles northwest, it does not. Products as above. Every vegetable on earth, nearly, yields enormously if watered. Corn averages 60 to 80 bushels per acre, grapes 5 to 10 tons, according to age of vines; five-year old grapes are in full bearing. Grapes bring $10 to $20 per ton delivered; corn 80 cents per cwt. in sack. All fruits grown, from apples to bananas. There is one large ditch which cost about $50,000. It is 12 miles long. There are smaller ditches to distribute water over 12,000 acres. The ditches are for the most part plowed and scraped out. A small part of the main ditch is cemented, and there is some cement piping. Water is sold at 25 cents per head of 100 inches. One head wets an acre in one hour. Larger portion of the valley is devoted to corn, hay, and stock, and is not irrigated.

The climate is mild, 26° above zero being the coldest for several years. Nothing was hurt by frost the past winter, and there was only one-fourth of an inch of ice on two occasions. The average winter temperature is about 60° above zero. The rainfall averages 15 inches per year. Don't think irrigation is healthy as a rule, nor the best for land, but prompt cultivation avoids injury.

The soil is as fertile as the delta of the Nile. A high range of mountains lies east and north, east and northwest of the valley. The Santa Aña River runs through the valley from the northeast to the southwest, and in summer all the water is used for irrigation. It is a medical opinion that extensive irrigation in the hot summer months will have a tendency to cause more or less sickness, though malaria cannot exist on account of the sea breeze that rises every morning in the summer. We have on an average from three hundred and thirty to three hundred and forty clear, calm days to the year.

Our rain falls from December to March, and is rarely very heavy. Vegetation makes a fine growth in the winter season; citrous fruits ripen and bloom then. The Eucalyptus tree makes its best growth then. The plowing is nearly all done then. Corn and ordinary vegetables are planted from March till June, and fall potatoes from August to October. Beets grow from year to year, and attain an enormous size. The castor bean grows to a large-sized tree, often over a foot in diameter, bearing a regular crop, which, however, is not very valuable. The ordinary house-plants grow in the garden and bloom the year round. A second crop of apples is frequent. This valley is particularly adapted to the growth of the English walnut, or Madeira nut. The olive thrives well here.

The town is 9 miles from tide-water, on Newport Bay, where small vessels come in. The soil is all a light-colored, sandy loam, very dry. Artesian wells are very common, and furnish the best drinking water. All the surface water is hard, and I think decidedly unhealthy for those affected with kidney disease. The drinking water is rain-water, kept out over night, which cools it nicely, as our nights are nearly always cool.

KERN COUNTY IRRIGATION.

The following report, in response to the Department's inquiries, is from Walter James, engineer in charge of the irrigation works of Messrs. Haggin & Carr:

BELLEVUE RANCHE,
Kern County, California, July 17, 1885.

J. B. HAGGIN, Esq., *San Francisco:*

DEAR SIR: In answer to your request for general information upon the subject of irrigation in Kern County, desired by the honorable Commissioner of Agriculture, as set forth in his letter to you of 27th April, 1885, I send you the following:

The area of land irrigated and under cultivation in Kern County is about 65,000 acres, about 50,000 acres of which is seeded to alfalfa, or lucerne. The lands not seeded to alfalfa are planted in cotton, broom-corn, hops, grains, gardens, vineyards, and orchards of the various kinds of fruit trees that flourish in this climate, such as the apple, peach, apricot, fig, pomegranate, orange, &c.

Land prepared for irrigation and seeded to alfalfa is valued at from $10 to $75 per acre, according to quality and amount of improvements; orchards, vineyards, and garden lands are valued at from $20 to $150 per acre.

There are in the valley portions of the country 400,000 acres of land which may be reclaimed by irrigation. By extending and enlarging the enumerated canals and their branches this area may be supplied with water. Besides this acreage there are, perhaps, 100,000 acres on the slopes of the hills which by a greater outlay may be brought under systems of irrigation in the remote future.

There are twenty-seven artesian wells in the country, some of which discharge as much as one cubic foot per second. It is in contemplation to use these wells of large flowage for irrigating, but up to this time they are only used for watering stock. Many of these wells are near natural water-courses and canals, and they were put down for the purpose of procuring more wholesome water for cattle than that flowing from the river. Many stock men claim that the saving in loss by disease in their herds more than justifies the expense of procuring artesian water, or pumping from wells instead of using the river water. With the exception of these wells and the water which flows down Poso Creek a few weeks in times of rains in the mountains, or when the snow melts, Kern River is the only source of water for irrigating in this county.

In average years from the 1st May to 1st August Kern River discharges about 3,000 feet per second, and in the other months from 500 feet to 1,200 feet per second. In unusual years it carries as high as from 9,000 to 12,000 feet per second.

The canals taking water from Kern River for irrigating are owned mostly by incorporated companies. They are in size, length, capacity, and cost as shown in the annexed table. Besides these there are numerous small canals constructed as a part of the cultivation of the land, of which no account is made. Many different methods of applying the water to the land from these canals are employed, according to the varying topography of different sections of land. Much of the land lying south of the river is irrigated in small areas by means of numerous small ditches. This system proves by experience to be well adapted to the kind of land to which it is applied.* Where the land lies favorably and is well prepared in this way, in half-foot levels instead of one-foot levels, as represented in the diagrams referred to, two men can distribute 500 feet of water per second at an expense of 2 cents per acre. This is on land set in alfalfa.

The average cost of irrigating land under the Calloway Canal is about 8 cents per acre for each irrigation. The cost of preparing land so that harvesting machinery may pass over the levees is from $100 to $200 per acre, exclusive of the cost of main and branch canals. The branch canals cost about $5 per acre. This system [that of the Calloway Canal] is somewhat extravagant in the amount of water required, but as these lands are irrigated but once or twice a year, and then at a time when the water in the river is in excess of all the wants of the country, the quantity of water used cuts no figure. The same is true of the system employed on a portion of the McClurg ranche, where large areas are inclosed between low hills by levees. A large volume of water, about 250 feet per second, is turned out on the land, and when the first level is filled the water is passed through a large gate into the next level, and so on. From the last level the water is drawn off into a branch canal. To prepare this land in this way with check levees and gates cost $2.50 per acre. It cost 5 cents per acre for each irrigation.

Another method is found to work well on very sloping land, where the slope is long enough to justify the necessary preparation. It consists of a contour gutter or ditch supplied from a main canal or branch. This contour is made to overflow through numerous small openings. The cost of preparing land in this way is from $1 to $2.50 per acre. Land prepared in this way can be irrigated for 10 cents per acre. When land is irrigated by numerous small ditches in small areas a thorough preparation of the land costs from $15 to $25 per acre. After this outlay it costs from 25 cents to 40 cents per acre to distribute the water for each irrigation.

This system is adapted to land that is very productive and where the water supply is limited. At present the duty of a cubic foot of water per second in this county is about 80 acres. Where the rainfall is greater or the atmosphere carries a greater amount of moisture less water is required, as in Los Angeles County, or that portion of the San Joaquin Valley nearer the bay, as in San Joaquin County. But it is thought that by a more thorough preparation of the land and the practice of strict economy even in this the driest portion of the valley a cubic foot of water per second can be made to irrigate from 100 to 125 acres. Since 1880 the Beardsley and McCord canals have been extended a few miles. Several weirs in the river and several new headgates have been constructed and some additional land has been brought under cultivation. But the progress made in the development of the possibilities of irrigation are insignificant compared to the expenditures previously made, as indicated in the cost of the works enumerated.

The construction of irrigation works and the improvement of the lands thereby supplied with water has been much discouraged by the attempts made to apply the doctrines of riparian ownership to the rivers of this State and the failure of the legislature to pass the needed laws governing the ownership and distribution of water. The scope of this doctrine of riparian ownership as sought to be applied to the rivers of this State is well expressed in the pleadings in the suits brought to enjoin parties from "in any manner interfering with the natural flowage of the water of river by, through, to, and over the said land of said plaintiff." Without such interfering with the natural flowage no canal can be operated nor may a man protect his farm from disastrous overflow in times of high water. In fact the success of this theory implies the confiscation or distribution of all the property created under the laws of appropriation.

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* See report of Public Land Commission 1879-'80, on Bellevue and McClurg ranches and the Calloway Canal.

In the valley portion of this county the average yearly rainfall is about 4 inches. During the spring and summer months the atmosphere is very dry. Under these conditions it is easy to infer the necessity for irrigation, and the almost worthlessness of the land without water. In their natural channels the rivers do not irrigate or make susceptible of profitable cultivation any land at all. The growth produced by the water flowing in natural channels is confined to a very narrow area along the banks, and this is wild grass of no great value. On the lands below the ends of the rivers, which are periodically submerged, the only growth is flags and rushes, which for forage are of little more value than that which would be produced on the same land by the rainfall. Of the water used for irrigation about 50 per cent. is consumed by the growing vegetation and by evaporation. The remaining 50 per cent. disappears downward. The continuous distribution of water in a section of country causes the water to rise under the ground until it comes near the surface or within reach of the roots of fruit or forest trees. It is thought also that the area of the artesian well belt will be extended by the use of water for irrigation, and that in time the water which is apparently lost will show itself in the lower portions of the valley and become available for other lands.

Annexed is a map of part of Kern County, with diagrams designed to illustrate the progress of irrigation enterprises within its limits.

DISTRICTS, CANALS, WELLS, WATER-RATES, ETC.

Mr. C. Brower, of Bakersfield, Kern County, sends the following notes on irrigation:

The irrigation area of Kern County may be generally described as a belt about 50 miles long, with a mean width of some 20 miles, lying between the Southern Pacific Railroad (which describes an irregular arc of a circle in passing through the valley portion of the county, on a line just above, or in the edge of the irrigational plane) and the extreme limits of the reclaimed swamp lands to the west and south.

The district, which is somewhat broader at the north, contracting in its circular course to the south and east, has a pretty uniform slope of from 6 to 10 feet, from its inner or more elevated edge, toward the circumference, thus presenting peculiarly favorable features for irrigation, and its very essential adjunct, drainage, without which the healthfulness of the country would be greatly impaired. Within this belt, paralleled with its outer edge and extending inward over about one-third to one-half its width, seems to lie another belt, described as the artesian-well belt, a continuation of the recently discovered and now famous artesian-well belt of Tulare County, which has been traced from King's River southerly, between the Southern Pacific Railroad and Tulare Lake, to a point as far south as Goose Lake, in Kern County.

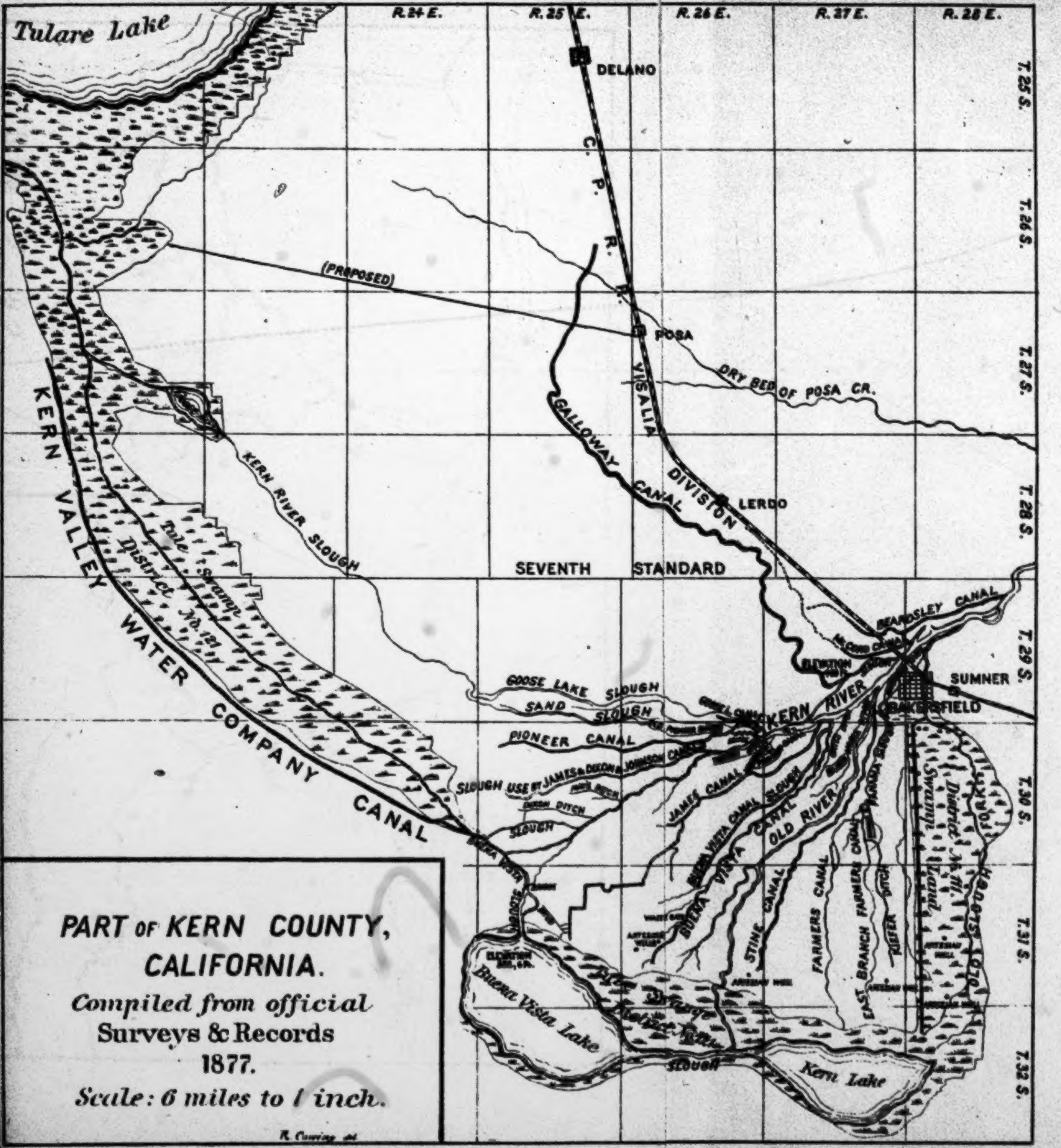
In this county about twenty wells have been bored during the past year, in the district lying between Goose Lake on the west and the towns of Paso and Delano on the railroad at the east, at depths varying from 400 to 700 feet, and additional wells are being bored as rapidly as possible with the labor available. The diameter of these wells is usually 8 inches at the top, decreasing according to the necessity for inserting smaller pipe within the larger in cases of obstacles or accident.

The flow, as stated by Mr. Walter James, engineer in the employ of Messrs. Haggin and Carr, who are reclaiming large tracts of desert land through their agency, varies from 2 to 13 inches over the top of the casing, giving a capacity of from half a cubic foot to 4 cubic feet of water per second with an irrigational duty of from 50 to 400 acres per well.

The well presenting the phenomenal flow last mentioned is said to be not one of the deepest, being less than 500 feet. No exploration for artesian water has as yet been made immediately south of the district above mentioned, but, several years since, a number of wells were bored in the vicinity of Kern and Buena Vista Lakes, in the extreme southern portion of the valley, to depths of from 250 to 460 feet, resulting in flows of from 2,000 to 10,000 gallons per hour. The temperature of the water from the artesian wells of the county varies little from 70° F., summer or winter.

LIST OF ARTESIAN WELLS.

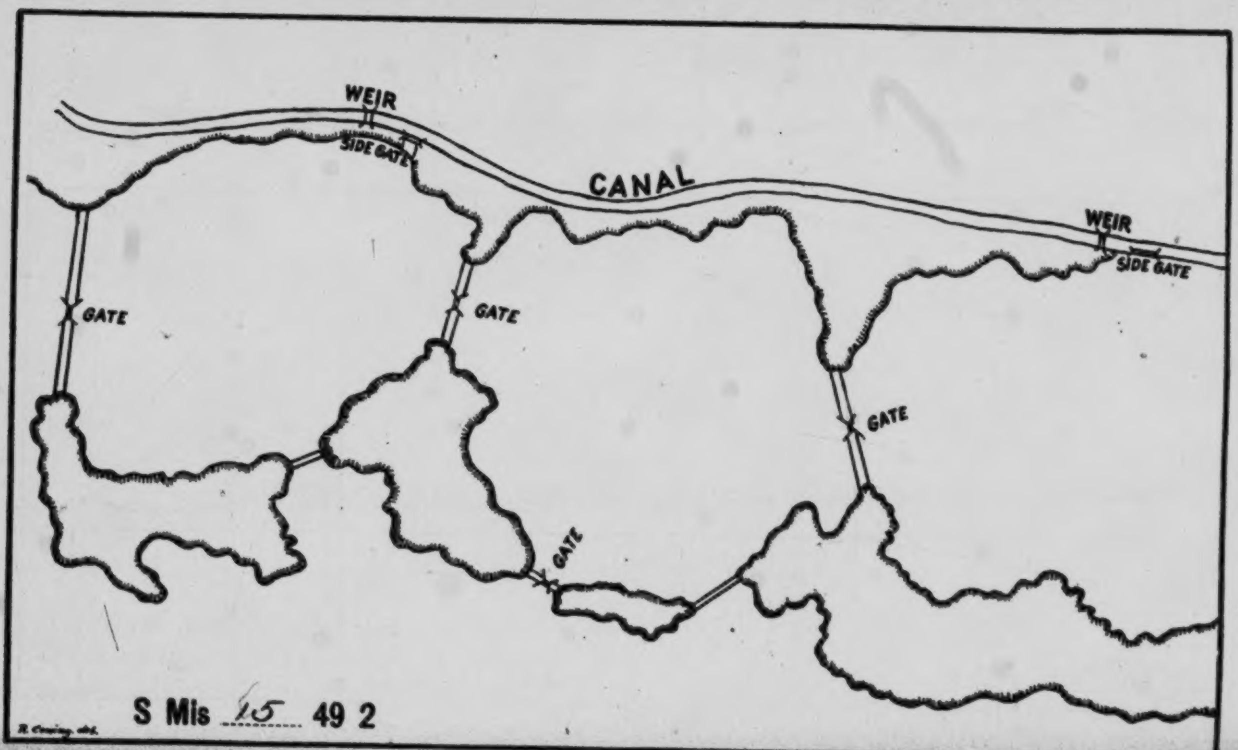
Mr. B. F. Mull, contractor for boring artesian wells, writes to Mr. Brower that the number of wells bored in Kern County is sixteen, viz:


Tulare Lake
R. 24 E.
R. 25 E.
R. 26 E.
R. 27 E.
R. 28 E.
T. 25 S.
T. 26 S.
T. 27 S.
T. 28 S.
T. 29 S.
T. 30 S.
T. 31 S.
T. 32 S.
DELANO
C. P. R. R.
(PROPOSED)
POSA
VISALIA DIVISION
DRY BED OF POSA CR.
GALLOWAY CANAL
LERDO
KERN RIVER SLOUGH
SEVENTH STANDARD
KERN VALLEY WATER COMPANY CANAL
Tule Swamp District No. 121
BEARDSLEY CANAL
McCORD CANAL
ELEVATION
SUMNER
BAKERSFIELD
KERN RIVER
GOOSE LAKE SLOUGH
SAND SLOUGH
PIONEER CANAL
JOHNSON CANAL
SLOUGH USE BY JAMES & DIXON & JOHNSON CANALS
DIXON DITCH
SLOUGH
BUENA VISTA
COYOTE SLOUGH
JAMES CANAL
BUENA VISTA CANAL
BUENA VISTA CANAL
SLOUGH
OLD RIVER
STINE CANAL
FARMERS CANAL
EAST BRANCH FARMERS CANAL
DUTCH DITCH
KIFFER
Swamp Land District No. 111
FORK OF HOUGHTON SLOUGH
ARTESIAN WELL
WASTE GATE
ELEVATION
Buena Vista Lake
Swamp Land District No.
SLOUGH
Kern Lake
R. Cowing del.

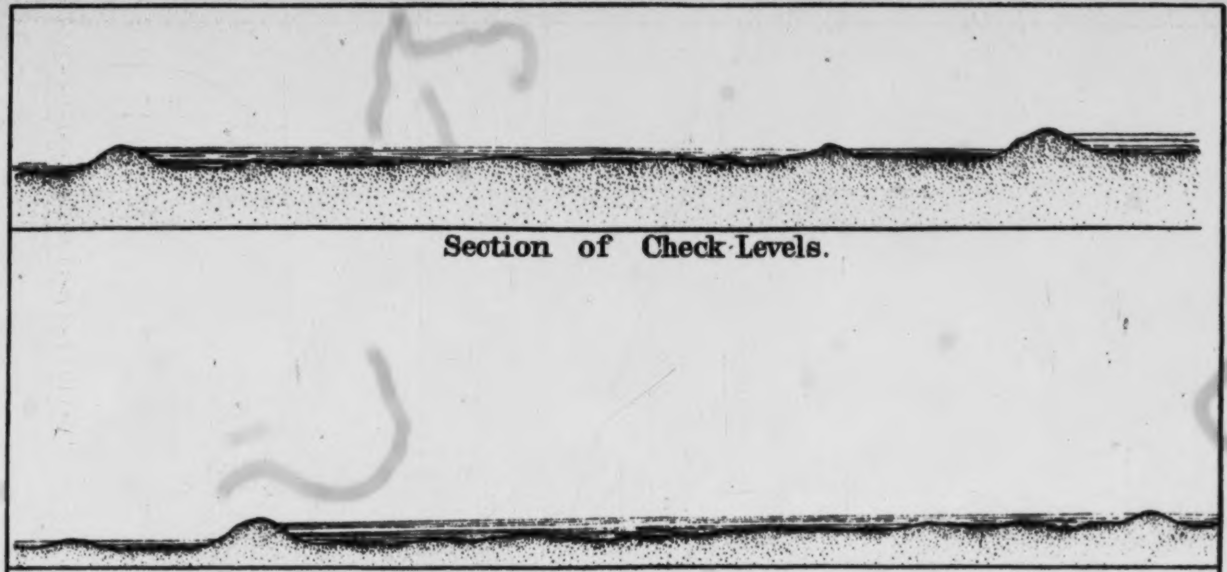
PART OF KERN COUNTY, CALIFORNIA.

Compiled from official
Surveys & Records
1877.
Scale: 6 miles to 1 inch.

S Mis 15 49 2


WEIR
SIDE GATE
CANAL
WEIR
SIDE GATE
GATE
GATE
GATE
GATE
R. Cowing del.

S Mis 15 49 2

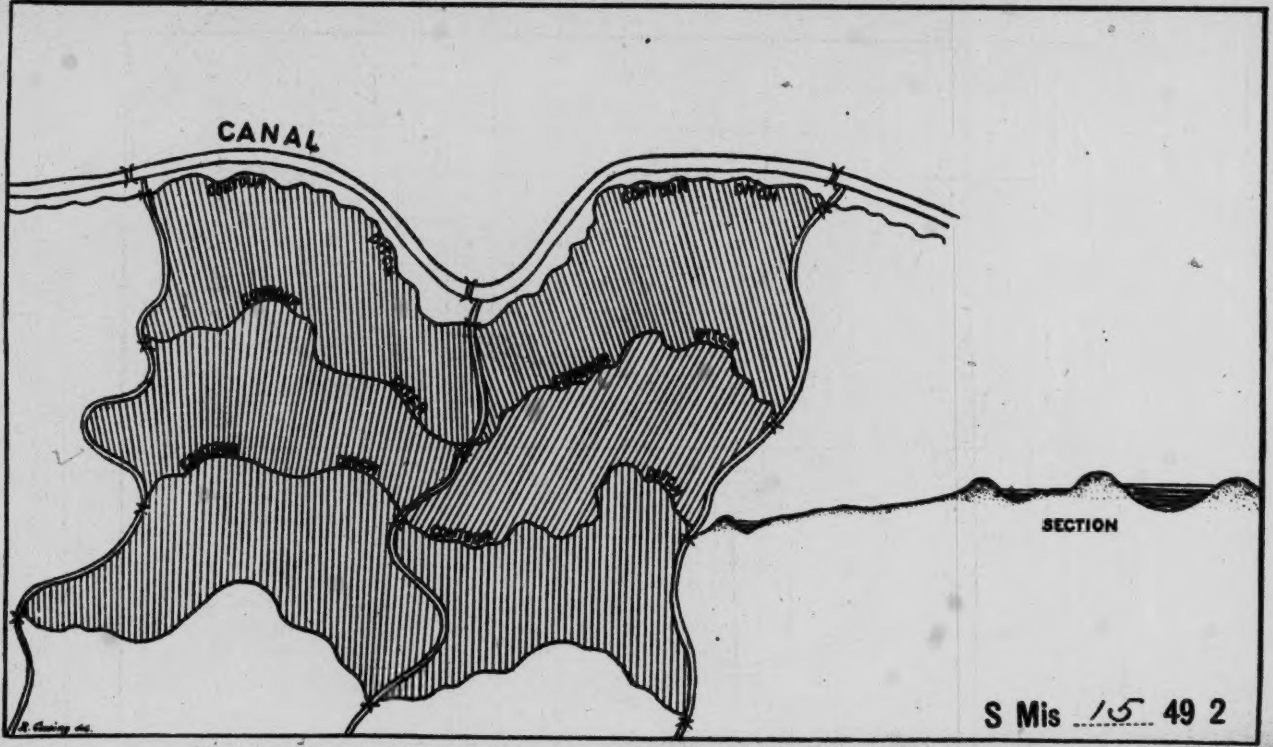


Section of Check-Levels.

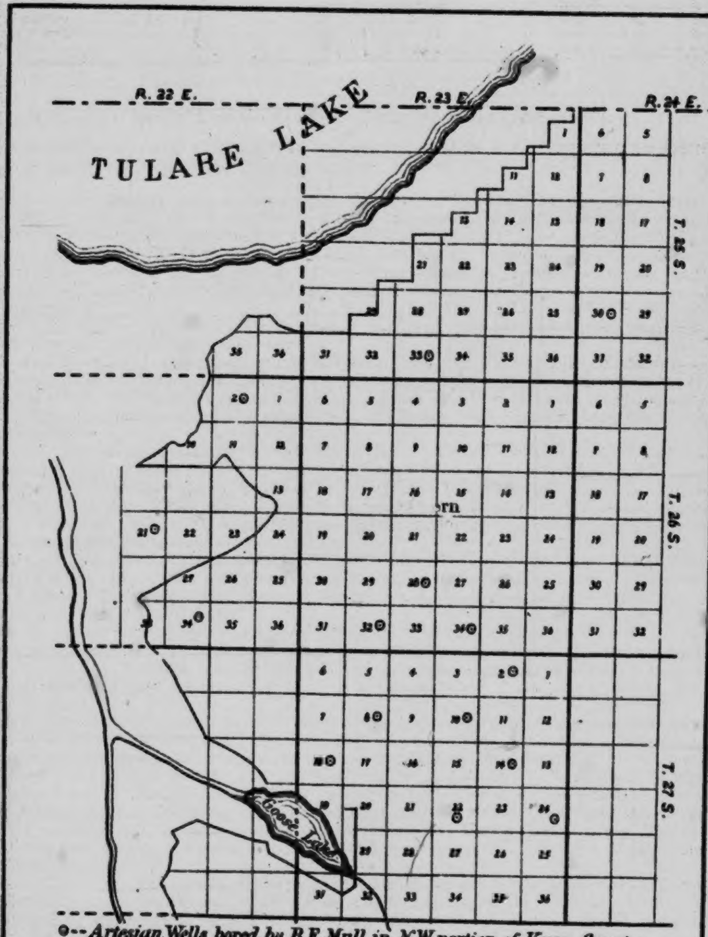
Vertical Scale: 5 Feet to an inch
Horizontal " 50 " " "

R. Cowing del.

S Mis 15 49 2


CANAL
CONTOUR DITCH
CONTOUR DITCH
SECTION

S Mis 15 49 2


TULARE LAKE
R. 22 E.
R. 23 E.
R. 24 E.
T. 25 S.
T. 26 S.
T. 27 S.
Goose Lake
ern

⊙--*Artesian Wells bored by B.F. Mull in N.W. portion of Kern County–December 1883 to December 1885.*

R. Cowing del.

S Mis 15 49 2

	Depth.	Flow.	Cost.		Depth.	Flow.	Cost.
	Feet.	*Inches.*			*Feet.*	*Inches.*	
J. H. Haskins, bored December, 1883, casing 8 inches.	374	4	$800	Henry's well	320	4½	700
				S H. Davis	234	5½	600
				I. M. Hutchin's	280	4	650
J. H. Blaisdell	253	5	500	D. Sewell's	310	2¼	725
J. D. Holden	625	4	1,500	E. C. Arnold's	358	9	850
J. H. Louttits	443	4½	1,100	W. H. May	425	8	1,062
Martin's well	450	5	800	I. M Hogan	369	12½	850
E. Phillips	380	3	750	G. A. Raymond	340	9	850
Ben Watrous	440	5	900				

Mr. Mull says a well of 4 inches flow will discharge about 8,000 cubic feet.

In regard to wells other than artesian, which are available to some extent for irrigation, Mr. Brower says:

A number of settlers have located upon the Government land in the southeastern part of this district, near the foot-hills, during the past year, and at depths varying from 25 to 40 feet have obtained water which it is thought can be cheaply raised [illegible] sufficient quantities for the irrigation of vines and trees. It is claimed that this section is in the thermal belt, free from frosts, which occasionally visit the lower lands of the valley, and therefore peculiarly adapted to the most delicate of the citrus and other fruits.

Water districts.—The land irrigable from Kern River may be described as naturally divided into six districts, as follows: *

First. The district lying between Old South Fork, the easternmost of the former channels of Kern River, Kern Lake, and what is termed Old River, comprising 80,000 acres, of which 32,000 acres are swamp land, almost wholly reclaimed, supplied with water for irrigation by the Kern Island, the Old South Fork, the Farmers, the Stine, and the Castro Canals.

Second. The district bounded by Old River, Buena Vista Lake and Slough, and the present channel of Kern River, comprising about 64,000 acres (of which 10,000 acres are unreclaimed swamp land), watered by the Buena Vista, James, and other minor canals and ditches. These two districts comprise Kern Island, with a total area of 144,000 acres, and within these boundaries are the major portion of the lands at present irrigated and cultivated in Kern County.

Third. The district north of Kern River, south and west of Goose Lake Slough, and east of the line of swamp and overflowed lands, watered by the Pioneer, Johnson, James, and Dixon, Dixon and Joice, Wible, Goose Lake, Railroad, and other lesser canals, comprising 70,000 acres.

Fourth. The district known as Swamp Land District 121 (or that portion of it lying north of the mouth of Kern River, comprising about 43,000 acres), and swamp land districts 184, 185, and 208, containing 59,768 acres, an aggregate area of nearly 103,000 acres irrigable in part by means of the Kern Valley Water Company's canals, partially completed.

Fifth. The district bounded on the east of the highest practicable grade line for a canal on the north side of Kern River (which may be taken as the grade line of the Beardsley Canal extended northward to the county line), and bounded on the west by Goose Lake Slough and the line of swamp lands, and south by Goose Lake Slough and Kern River. The total area of this great district is about 360,000 acres, of which about 60,000 acres is above the grade line of the Calloway Canal. That portion of the district near the river is commanded by the Beardsley, McCord, McCaffrey, Emery, and Jones and Tuckey Ditches, while the Calloway extends northward nearly over its whole length.

Sixth. The lands lying east of Kern Island, and bounded north, east, and south by the foot-hills and mountains, properly from a distinct district, a portion of which may be covered by a projected branch of the Kern Island canal, and all of the district would be commanded by a projected canal from the mouth of Kern River Cañon. There are about three townships, or nearly 70,000 acres of arable land in this district. The whole area of land that may be covered by completed or projected works for irrigation from Kern River, therefore, foots up 747,900 acres. Of this area, about one-third cannot be considered irrigable, as it is not, and probably cannot be made, susceptible of profitable cultivation, leaving but about 475,000 acres of irrigable land, of which about 8 per cent. has been irrigated.

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* See Report of State Engineer of California, 1880.

KERN RIVER AND OTHER CANAL WORKS.

The main source of Kern River is in the ice fields and beds of snow of the Sierra Nevada, which, during the summer, furnish a certain supply of water, long after the winter rains in the lower mountains have drained away, and secure a full flow through the first seven months of the year, the season of the greatest demand. In some seasons the maximum discharge occurs during the first three months of the year; in others in the months of May, June, and July; but ordinarily there are two periods of extreme flow each year—the rain flood of winter and the snow-water flood of summer. The season of lowest water occurs in October, after which the stream begins to increase. The area of mountain snow-fall and water-shed is 2,382 square miles. The discharge per square mile of drainage area was 20 cubic feet per second in 1879, but the average is 23 feet per second. The minimum discharge for the same year was 146 cubic feet per second for a few days.

The ordinary maximum discharge is 4,800 cubic feet per second and the mean discharge during the irrigating season is 3,000 cubic feet per second. In the year 1867–'68 an extraordinary flood occurred, giving a discharge of 29,000 cubic feet per second, which was supposed to be the result of a land slide blocking a valley, thus forming a storage embankment that gave way. Such a flood occurring now, would cause serious damage to the irrigating works, but it is not feasible, from an economic point of view, to provide against such a contingency.

More canals have been diverted from the Kern River than from any other stream in California, its low banks and the rapid slope of land away from it making it a simple and not expensive matter. Canals, consequently, have multiplied to an undesirable extent, rendering it difficult to control, apportion, and measure the supply to each claimant, and this has caused serious disputes.

Two main canals, diverted from the river where it emerges from the foot-hills, of sufficient capacity to serve the whole irrigable area, would not have exceeded the aggregate cost of the many that are now in existence.

It would have effected the distribution more equitably than is now accomplished, and with less loss of water in the canals themselves, and would have avoided the greater loss that takes place in the river bed before the works lower down are reached. The lowest maximum discharge that has been observed since irrigation commenced, was in May, 1879 (a year of remarkable scarcity), when it was 1,231 cubic feet per second. The stream is composed of shifting quicksands, and is of irregular width, from 150 feet to 800 feet. The banks are low and unstable, consisting of sandy alluvium. The course of the river has frequently changed, and the channels, which were once main branches of the river, have been converted into canals, the flow of water in them being controlled by head-gates. The total number of canals, large and small, is 33, and their length 275 miles. Kern River and the delta that it traverses have a slope of from 6 feet to 8 feet per mile, which, together with its sandy bed and low banks, constitute the most favorable conditions to take off water at almost any point, at a minimum of cost, by means of wing-dams of sand and brush running out into the channel at an acute angle up the stream. These wing-dams are liable to be swept away with every freshet, but as they are inexpensive no serious loss is entailed.

To avoid this frequent renewal of the wing-dams, a dam was constructed across the river of brush mattresses, staked and weighted down with gravel; it rested upon a bed of quicksand, which was constantly being undermined, and every freshet scoured a hole through the body of the dam. It was consequently abandoned, and the canal was extended up stream about a half mile and a wing-dam again resorted to.

The brush-mattress dam cost originally $7,000, and with subsequent repairs, during three years, nearly $12,000. Consequently timber weirs were resorted to. Many of these have also failed; they were all on the original mode of construction, but none of those constructed on the last principle have given way.

The earlier form of construction consisted of inclosing the area to be built on with sheet-pilings 10 feet to 12 feet long. This area is covered over with a floor placed one or more feet below the bed of the channel. The later constructions have a second floor two or more feet above the first, with walls forming compartments that are filled with sand. In addition the bed of the river immediately above and below the transverse sheet-pilings is protected with sand boxes, 10 by 2 feet, that act in the same manner that stone-pitching or sand bags do similarly situated, viz, by sinking and protecting the bed where it is eroded by the concentrated action of the water. These works are built entirely of wood, there being no stone available in the vicinity. The reduction of these works to the least possible figure must be at the sacrifice of permanency, but they certainly answer the purpose perfectly at present. For irrigation schemes that have been well considered and that are to be carried out to the full capacity of the water supply, or extent of land to be irrigated, the works should be built with a view to permanency, as far as the most desirable timber can secure this object, masonry being too costly to be considered.

WATER RATES.

Mr. Brower states that under provision of law all water rates are fixed by the board of supervisors of the county in February of each year. The rates now in operation on the Kern Island Irrigating Canal are as follows:

General rates.—For agricultural lands beyond the limits of the town of Bakersfield, $2.16 per foot per day of twenty-four hours; the theoretic discharge being at the rate of a cubic foot per second, and no delivery being made of less than one-half foot, through an aperture of 12 by 6 inches, for a single day, or one-twelfth foot (through an aperture of 12 by 1 inch) per day by the month.

Town rates.—(In the town of Bakersfield and on small lots and tracts adjoining, supplied through the town system of works):

House lots, &c., 25 cents per hour for a 24-inch head.

Orchards, gardens, &c., of one-half to 2 acres in area, in heads of 48 inches; smaller heads (not less than 24-inch by the day or 12-inch by the month) 3 cents per inch per day, or 2 cents per inch per night of twelve hours.

Farming lands, orchards, &c., upwards of 2 acres in extent, at the general agricultural rates.

Sprinkling carts, $10 each per month. Other use in bulk, 2½ cents per 1,000 gallons.

Live stock.—Horses and cattle, per 1,000 head per year, $100; smaller numbers and less time in proportion, except migratory stock, per 100 head, each watering, 50 cents.

Sheep and hogs, per 100 head per year, $33.33; smaller numbers and less time in proportion, except migratory stock, each watering, 18 cents.

EFFECT OF IRRIGATION.

The effect of irrigation upon vegetation under the warm sun of the valley is to stimulate it to rapid and luxuriant growth, but if pushed to excess quality is apt to be sacrificed to quantity, and the productions become stalky, overgrown, or watery, and insipid to the taste. A moderation in the temperature in summer has been most noticeable, while a temperature of 110° F. in the shade was reached in the town of Bakersfield at times up to the years 1875 and 1876. The same exposure of the thermometer has not shown a higher degree than 104° since, and rarely higher than 102°. This may be due in part, however, to the thinning out of the timber in the vicinity of the town, and clearing the banks of the neighboring sloughs of the dense undergrowths which formerly checked the prevailing breeze from the coast, as well as to the vast fields of cooling alfalfa which now take the place of the bare ground glowing under a burning sun.

Similarly an increase of rainfall has followed general irrigation, though how far this may be a result is not certain. According to information kindly furnished by the agent of the Southern Pacific Railroad at Sumner, from the official record of his office, the rainfall at that point during the past five years has been as follows, viz:

For the year ending—	Inches.
June 30, 1882	2.92
June 30, 1883	3.96
June 30, 1884	9.20
June 30, 1885	7.47
For the half year ending December 31, 1885	3.25

The record of previous years, he states, have all been sent to the engineer's office in San Francisco.

Not only has the rainfall been greater, but a greater number of cloudy days, heavier dews, and more frequent fogs have prevailed during the past three winters, the one now closing having been noted for a degree of humidity unparalleled in the recollection of the early settlers.

The bottom lands of the valley are devoted principally to alfalfa and stock raising, or dairying, for which they are admirably adapted, though corn is here raised to considerable extent, and numerous Chinese market-gardeners seek this locality for its great fertility and natural moisture, the subterranean waters frequently rising to within 4 or 5 feet of the surface. Hops and cotton are raised on these lands, also, to a limited extent, from year to year, but the costliness of labor—ordinary field-hands commanding $25 to $30 per month and board—renders it doubtful whether these crops could at present be raised at a profit.

The higher irrigable lands are preferred for wheat growing and mixed agriculture. Alfalfa does well on them when sufficiently irrigated, and makes a superior hay, because of its finer stalk; but it does not exhibit the luxuriance of growth found in the lower lands. Egyptian corn has been tried experimentally on the high planes north of Kern River, and with marked success, under circumstances of drought that would prove fatal to other cereals; but the destructiveness of birds, and the absence of a demand for it in the market have discouraged its cultivation to any extent.

Fruits have been raised in the valley to a limited extent only, by way of experiment, or for domestic use; but the entire range of fruits, both hardy and semi-tropical, have been produced here in a perfection not excelled in the most favored regions of the State. On the alluvial bottoms apples, pears, peaches, apricots, nectarines, plums, prunes, quinces, and the Japan persimmon grow, of superior size and excellence, without irrigation beyond the first year or two. In the warmer, sandy, and gravelly loams of the mesas, where the necessary irrigation can be had, figs, almonds, pomegranates, and grapes find most favorable condition of soil and climate, and the more sensitive orange, lemon, and even the banana have been successfully grown in the open air.

It is proper to state, however, that under the present limited experience with these more delicate fruits, their cultivation on an extensive scale on the open plains is considered too hazardous to attract serious attention, though many of the more elevated slopes, and sheltered valleys of the foot-hills are almost wholly exempt from frosts. There are few parts of the State where the value of land is not enhanced by facilities of irrigation; but in this valley, with its slight rainfalls and dry air, they constitute the main factor in determining values.

Lands otherwise desirable, but destitute of irrigational facilities, are held as low as $2.50 per acre, or even less. The same class of lands, with ditch connections, would sell for $25 to $50 per acre, the latter being the highest figure asked, unless for tracts exceptionally favorably located, in the immediate vicinity of the town of Bakersfield.

THE MERCED CANAL ENTERPRISE.

Merced County lies in the shadow of a part of the Sierra, and contains 1,250,000 acres of land. There are less than 100 miles of canal and ditches in Merced, and only a few of its inhabitants enjoy perfect privileges of irrigation. It has a population of 8,000.

In 1849, a Mr. Huffman, of Saint Louis, came to California, and located in Stockton, and after many successful speculations in land in the neighborhood of the town of Merced, repurchased and retained thousands of acres of the lands he had sold. Three or four years ago he visited Merced Falls and the higher water of the Merced River, and the thought struck him if all that water could be saved and turned upon the half million acres of excellent land, it would be instrumental in developing all the resources of Merced County, and in time support a population of at least 50,000 people. Shortly after he went to San Francisco, and, meeting Charles Crocker, stated what he had seen and thought, and the facilities for irrigating at least 400,000 acres of lands, by the construction of a canal which should connect with the Merced River where it springs out of the granite foot-hills.

Mr. Crocker, ascertaining the cost of construction of the canal to be $1,000,000, authorized Huffman to go on with the work. He returned to Merced, and on the 1st day of March, 1883, work was commenced on the main ditch, which, with its branches, has assumed vast proportions. The canal taps the Merced River at a point a short distance above where the Farmers' Canal was taken out, at a curve in an abrupt bluff along the first terrace of the foot-hills, in the northeastern part of the county, and meanders in a southwesterly direction. The whole length of the canal and its branches when completed will be upwards of 75 miles, and it will carry water enough to irrigate nearly 300,000 acres of land in Merced County and 75,000 acres in Fresno. The main canal, for a distance of 8 miles, has enough elevation to give it the fall required, and is 100 feet wide at the top, 70 feet at the bottom, and carries 10 feet of water, or 3,400 cubic feet per second. At a point 6 miles below the river the canal passes through a tunnel, under a hillock of solid rock 1,600 feet in length, or, with its approaches, 4,400 feet.

The general grade of the canal is 1 foot to the mile, and, as a general thing, is 30 feet wider at the top than at the bottom. There is a macademized road, 12 feet in width, upon the upper side of the canal, except where the water passes through the tunnel. A huge dam or reservoir is being constructed 8 miles from the head-gate at the river, and from this dam are three unfinished branches, or a continuation of the main canal and two branches. The north branch will be about 25 miles in length, and carry 1,000 cubic feet of water per second.

The middle branch or continuation, carrying 1,000 cubic feet per second, is about 15 miles in length, traverses the county in a southwesterly direction, and crosses the railroad track some 5 miles northwest of Merced. Upon leaving the dam it meanders along the bed of a "dry creek" for most of its distance. The south branch, which may be considered a portion of the main canal, will be 25 miles in length, and will carry 1,500 cubic feet of water per second. It will be 90 feet wide at the top, 50 feet at the bottom, and have a depth of 8 feet of water.

This branch follows along the foot-hills for some distance, then passes to the north and east, then again follows the foot-hills to a point east and reaches Bear Creek, then meanders south to the Chowchilla River. There is a tunnel in this branch nearly constructed, 2,200 feet in length, under a gravelly foot-hill. A large section of country, for many miles east of Merced, may be brought under cultivation by irrigation through the influence of this southern branch.

The town of Merced will be directly benefited, as it is the intention of the owners of the canal to lay off a reservoir of 400 acres at a point about 7 miles northeast from Merced. This reservoir will have a depth of 30 feet and an elevation above the town of 90 feet, and connect with it by means of a foot pipe. This branch has reached the above point and is being pushed rapidly towards its terminus at the Chowchilla River. Water will be turned in and run through nearly 60 miles of canal in a month or two, from which 200,000 acres may be irrigated.

The following replies are in response to the Department circulars, and are inserted here in order to group together all the facts relating to the Merced canal and land enterprise.

The colony tract of Merced County includes 26,000 acres of land in townships 6 and 7, ranges 12 to 14 east, all owned originally by Charles Crocker and C. H. Huffman, and subdivided by them and offered for sale in parcels from 20 acres upwards, with permanent water right annexed to each parcel of land. All colony land lies within 7 miles of the town of Merced, and before the completion of the present irrigation land was used for winter and spring sheep pasture, and to some extent for wheat growing.

The value of the present colony land in 1880 was from $2.50 to $5 per acre. Present value, as indicated by recent sales, is from $25 to $75 per acre. Water rights sufficient to insure perfect irrigation are appurtenant to each acre of colony land, and pass to the purchaser and all subsequent holders of the lands.

Products of the land under irrigation are annual grain crops, corn, sorghum, root crops, including sweet potatoes, alfalfa, grapes, and all varieties of tree fruits—lemons, figs, oranges, &c. Value of grapes delivered in bulk at Merced, $20 to $30 per ton, as per quality. Dried fruits, $75 to $100 per ton in car-load lots.

The Merced colonies are supplied permanently with irrigation water by the Merced Canal and Irrigation Company.

This irrigation enterprise embraces a mileage of canals and irrigation ditches estimated to supply an area of 350,000 acres of land on the Merced plains with water for permanent cultivation. The main canal as completed is 80 feet wide at the bottom and 100 feet on top, and carries a body of water 10 feet deep, with a fall of 1 foot per mile. The present length of this canal is 26 miles. The water supply is taken from the Merced River. This stream heads in the perpetual snow regions of the Sierras above the Yosemite Valley, and at the lowest stage of the river in dry seasons affords sufficient water to fill the canal to its full capacity continuously. Over $800,000 have been already expended in the construction of the company's works by Messrs. Crocker and Huffman. For colony service and the irrigation of a large area of outside land on the plains, the works are completed.

The estimated cost of the whole enterprise to irrigate the 350,000 acres of land on the Merced plains is $1,500,000. At present, less than one-fifth of this tract is susceptible of profitable cultivation for the product of grain. The remainder is devoted to stock ranges. As regards the climatic conditions of the land reached and intended to be reached by the works of the Merced Canal and Irrigation Company, it may be said that there is generally a clear atmosphere, summer and winter, with a variable rainfall, generally light, and often insufficient to produce cereal crops. Pastures are dependent on the amount of early rains. The summer heat is invariably modified by uniform trade winds. Three thousand acres of land continuously irrigated for seven years by a small canal, the predecessor of the present canal, lie adjacent to the present colony tracts. These 3,000 acres include the Buhach plantation and vineyard and garden, cultivated by Italian settlers on the Merced plains. No malarial results have attended the distribution of irrigation water on any part of the plains, the winds adverting malarial tendencies.

The character of the soil of the Merced Colony tracts varies from sandy to clayey black soil, but is alike fertile, productive, and inexhaustible when irrigated sufficiently.

Rainfall from 1878 *to* 1886, *as shown by rain gauge of C. H. Huffman, Merced, Cal.*

	Inches.
1878	
1879	13.77
1880	6.24
1881	12.45
1882	13.05
1883	9.73
1884	11.17
1885	23.13
1886	8.40
	13.17
Average	12.34

COLONY OF PASADENA.

The present population of Pasadena is supposed to be about 2,000. It is growing rapidly, because known as a great sanitarium for persons suffering from pulmonary diseases. It is not yet an incorporated town. The soil is granitic silt of great depth and uniform quality. The capillary attraction of this soil is so great as to overcome the attraction of gravitation, so that what water the soil contains is equally diffused, regardless of depth, and does not increase with depth so as to collect in wells. An artesian well sunk 400 feet failed to strike water. Only one common well exists. It is 100 feet deep, and has only 3 feet of water at the bottom. Water in this region appears in perennial springs, called "cienegas," which are not affected by the hygrometric condition of local atmosphere or season. A few miles east there is an underground water-bearing stratum, in which artesian or "driven" wells strike flowing water at about 100 feet. The same formation occurs in other parts of the county, giving enormous value to lands on the surface.

In the spring of 1873 a party of gentlemen residing in Indiana examined the southern portion of California and determined to purchase the half interest in Dr. John S. Griffin's rancho, San Pascal, located on the east bank of the Arroyo Seco, at the west end of the San Gabriel Valley, sheltered on the north by the Sierras and on the south by the Verdugo mountains. The reasons for this choice were, the nearness to the railway and the city of Los Angeles, as a base of supplies and market for crops, and its elevation above the sea of 1,000 feet, making it advantageous for those suffering from catarrhal or bronchial affections. The topography of the ground is so diversified as to give a fine outlook to all parts of the tract, which has a warm, rich soil, so retentive of moisture that it is admirably adapted to the cultivation of semi-tropical fruits.

A company was formed, called the San Gabriel Orange Grove Association, and about 3,700 acres of land were purchased. The water was brought about 3 miles in an iron pipe to a reservoir on the highest point of 2,400 acres of land, and from the reservoir, by a main pipe down the center of the tract, with distributing branches over a tract of 1,500 acres. Each shareholder was given 7½ acres of land and an undivided interest in the remainder of the land and water. A portion of the timbered land in Arroyo Seco was subdivided into small tracts, and sold to the stockholders, the proceeds being applied to the further development of water from springs in the Arroyo Seco Cañon. Since that time the balance of the land, 1,300 acres, has been sold, and additional land containing springs purchased. The land was purchased December, 1873, the survey and subdivision made January, 1874. Little was done towards cultivation until the winter of 1874–'75, when 15,000 fruit trees and 100,000 vines were planted. The commanding position of the place at the head of the valley suggested a name signifying "Crown of the Valley;" accordingly the Indian name, Pasadena, was adopted.

In the spring of 1876 the lands of the Lake Vineyard Land and Water Association, adjoining the lands of the Pasadena colony on the north and east, were subdivided by the owners into 10-acre tracts, with the Pasadena streets extending through them. A concrete ditch was made from the springs in the Arroyo Seco, extending about 2 miles, to reservoirs connected with iron pipes. The reservoirs have a storage capacity of 30,000,000 gallons, and leading from them are subterranean pipes through which the water is taken to the houses and lands on either side. The land is rich table-land, with a southern slope, making irrigation easy and rapid.

The most enlightened system of cultivation, with but little irrigation, has been carried on, until 250,000 fruit trees and the same number of vines have been planted and are steadily coming into bearing.

IRRIGATION CANALS.

List of irrigating works in Southern California, furnished by the Immigration Association of California.

The Selma Canal and Irrigation Company, Selma, Fresno County.
The Anaheim Water Company, Anaheim, Los Angeles County.
The Cajon Irrigation Company, San Diego County.

The Riverside Canal Company, Riverside, San Bernardino County.
The Sacramento Valley Irrigation Company.
The Lugonia Water Company, Lugonia, San Bernardino County.
The Santa Ana Valley Irrigation Company, Santa Ana, Los Angeles County.
The Farmer Irrigation Company.
The Seventy-six Land and Water Company, Traver, Tulare County.
The People's Irrigation Company, Tulare County.
The Mussel Slough Company, Hanford, Tulare County.
The Last Chance Company.
The Lower King's River Company, Fresno and Tulare Counties.
The Rhoads Ditches.
The Settler Company.
The Lakeside Company.
The Kings River and Fresno Canal Company, Fresno.
The Centreville and Kingsbury Company.
The Fowler Switch Canal Company, Fowler, Fresno County.
The Emigrant Company.
The Liberty Canal Company.
The Upper San Joaquin River Canal Company.
The Chowchilla Canal Company.
The Farmer's Canal Company.
The San Joaquin and King's River Canal Company.
The Natoma Land and Water Company, Folsom, Sacramento County.
The North American Canal Company.
The Excelsior Canal Company.
The Stanford Canal.
The Fresno Canal, Fresno City, San Joaquin Valley.
The Grant Canal, San Joaquin Valley.
The Murphy's Slough Canal, San Joaquin Valley.
The Kincaid Canal, San Joaquin Valley.
The Southerland Slough Canal, San Joaquin Valley.
The Lower King's River Canal, San Joaquin Valley.
The Rhodes Canal, San Joaquin Valley.
The King's River Canal, San Joaquin Valley.
The Beardsley Canal, San Joaquin Valley.
The McCord Canal, San Joaquin Valley.
The Calloway Canal, San Joaquin Valley.
The McCaffrey Canal, San Joaquin Valley.
The Emery Canal, San Joaquin Valley.
The Jones and Tucker Canal, San Joaquin Valley.
The Railroad Canal, San Joaquin Valley.
The Wibble Canal, San Joaquin Valley.
The Goose Lake Canal, San Joaquin Valley, from King's River.
The Pioneer Canal, San Joaquin Valley, from King's River.
The Edwards Canal, San Joaquin Valley, from King's River.
The James and Dixon Canal, San Joaquin Valley, from King's River.
The Johnson Canal, San Joaquin, from King's River.
The May Canal, San Joaquin Valley, from King's River.
The Dixon and Joice Canal, San Joaquin Valley, from King's River.
The Kern Island Canal Kern Island Valley, from King's River.
The South Fork Canal, Kern Island Valley, from King's River.
The Castro Canal, Kern Island Valley, from King's River.
The Stine Canal, Kern Island Valley, from King's River.
The Baker and Noble Canal, Kern Island Valley, from King's River.
The Gates Canal, Kern Island Valley, from King's River.
The Buena Vista Canal, Kern Island Valley, from King's River.
The James Canal, Kern Island Valley, from King's River.
The Plunkett Canal, Kern Island Valley, from King's River.
The Meacham Canal, Kern Island Valley, from King's River.
The Wilson Canal, Kern Island Valley, from King's River.
The Henley Canal, Kern Island Valley, from King's River.
The Frazier Canal, San Joaquin Valley, from King's River.
The Kern Valley Water Company, Bakersfield, San Joaquin Valley.
The Azusa Canal, Los Angeles and San Bernardino Counties.
The Duarte Canal, Los Duarte and San Bernardino Counties.
The Peck's Ditch, Los Duarte and San Bernardino Counties.

WATER RIGHTS AND STATE POLICY.

At the State Irrigation Convention of 1884, held at Riverside, Southern California, Mr. William Ham Hall, the State engineer, made a remarkable address covering the subject of irrigation laws, works, and administration. Engineer Hall is unquestionably one of the best American authorities on this subject. In the preparation of this report the Department has been greatly aided by his reports and suggestions. Mr. Hall's address is so clear, lucid, and comprehensive that it is appropriate to summarize and quote its principal suggestions. He sums up the main questions which arise in the development of irrigation as follows:

> (1) To what lands or claimants are waters to be allotted, as to what measure in each case, and as to what scales as to priority of right?
>
> (2) According to what system are the rights or privileges to the use of water to be availed of?
>
> (3) Upon what basis of credit can money be raised to bring the water to the land, and under what business organization may this be effected?
>
> The first question is purely a question of water rights or privileges.
>
> The second is a question of *administration* of the rights or privileges.
>
> The third is a question of *application* of such rights or privileges. These are properly the "problems of irrigation," and, taken together, they constitute the "irrigation question." All other questions are secondary to these. These fundamental questions cannot be and never have been settled by a policy of non-intervention by the Government of any land.
>
> In California there are two general classes of conflicts. They are, (1) conflicts between *rival appropriators* of water; and, (2) conflicts between appropriators and riparian owners. Of course there are an infinite number of sub-variations of cases which come up under each of the general classes. In the San Joaquin Valley another question comes in, giving rise to what Mr. Hall regards as the worst conflict of all, namely, that between appropriators of water for irrigation and the navigation interests on the main river.

To do away with these clashings of interest Engineer Hall does not advise that the State take entire control of irrigation matters. He argues that the outlay for the satisfaction of claims would be too great; that the construction of works would be too costly; that unless the water supply should be enough under a reapportionment to satisfy both classes, the conflict between appropriators and riparian owners would continue, and that it is altogether impracticable to condemn the right of navigating a public stream. Mr Hall continues:

> I would propose, as the solution of the irrigation question, that the State shall direct and control the diversion of waters from the streams; insist upon their economic use; see that the riparian proprietors are supplied with water for stock and domestic purposes, at least, if they cannot all come in for a share of the water for irrigation; see that all lands naturally dependent upon a public source of supply get their share, as far as the supply will go, upon some reasonable terms; see that the rights or privileges which have accrued, or may in the future accrue, be respected without necessitating recourse to the courts in every instance of conflict, and see that sufficient water is left in navigable streams to satisfy the interests of commerce at stated seasons when most needed.

He suggests the passage of laws which would—

(1) Define the nature of existing water privileges and provide for a record thereof.

(2) Establish control and provide for the care of all streams for the use of their waters in proportion to claimants, and for the distribution impartially of all water not strictly private property; establish a unit of measurement; adjust conflicts between irrigation and riparian claims; protect river navigation and regulate the economic diversion of waters therefrom; carry forward experiments as to use and distribution "without material loss or waste," and establish general regulations for economic use, and to insure good and sanitary drainage.

Mr. Hall says:

> The plan which I have outlined contemplates:
>
> (1) State regulation of the public sources of supply, the streams, and of waters allotted to claimants from those sources.
>
> (2) District or private regulation, under general State laws, of the details of distribution from the canals to the irrigators.
>
> (3) State regulation of the use of water in irrigation, to the end that none be wasted.
>
> (4) State adjustment of conflicting rights by arbitration, when possible, or by condemnation where necessary and possible.
>
> When this much has been accomplished there will then be a good basis of credit in irrigation property. Capital can be obtained for the construction of irrigation works whenever it is known that there is a good and sufficient water right for irrigation.

The California engineer enters into an elaborate exposition of the State laws of Colorado, as seeking to accomplish these things. What he says thereon is quoted at some length:

> We are not without a precedent for the course which I propose for California in this matter. Colorado is an irrigation country, having larger canals and more of them than has California. I have had my pride as a citizen of this State somewhat taken down, of late, by looking into the affairs of irrigation in Colorado. They had there, a few years ago, a perfect chaos with respect to water rights. Litigation reigned supreme, as it reigned here. But in 1879 they passed a law providing for an examination into the subject of water rights and irrigation, and in 1881 they passed a law providing for the proper proving up and recording of water-right claims and the administration of the affairs of the waters and streams. I have here a copy of that law. It is called "An act to make further provisions for settling the priority of rights to the use of water for irrigation, in the district and supreme courts, and for making record of such priorities, and for payment of costs and expenses incident thereto."
>
> It provides, first, that every claimant of water by appropriation shall, on or before a certain date, file with the clerk of the county, &c., a statement, under oath, and according to a prescribed form in some particulars, of the extent, nature, and history of the development of his claim.
>
> It then provides for certain publications and records of publications.
>
> It next provides for a judicial inquiry into the status of the various water claims for each of the several sources of supply.
>
> The dates, extent, and localities of all appropriations, constructions, and enlargements of canals are required to be proved up before a court referee.
>
> This referee is required to make findings of fact with respect to all water claims in the district brought to his notice, and report them, with the evidence, to the court.
>
> The court is then required to give all parties a hearing on this report and finally to enter a decree declaring the extent and relative priority of each claim. This decree forms the basis of future distribution of waters from the stream to the canals in each case, which is done by a water commissioner for each district.
>
> The State furnishes the expert service to keep measurement of the waters in the streams and gauge the canals and headgates, upon which data and the decrees and the renewed or extended claims made from time to time the water commissioners act in their distribution work.
>
> It will be seen that this is a system whereunder the State undertakes to regulate the distribution of waters from the streams to the canals according to the decreed rights of each.
>
> It is a system of account keeping of the waters available for diversion, and an adjustment of balances by executive officers. Quarrels between appropriators are settled once for all in the courts, and thereafter their affairs are kept out of court.

Mr. Hall gave also an interesting account of the workings of this plan, quoting chiefly from the judicial decisions made in "Water District No. 9." He finds in them and the laws under which they are made a just basis for the adjustment of water-right difficulties.

> Colorado [he says] started in by declaring in its constitution that the waters of the streams were the property of the State, and they should be used primarily for irrigation.
>
> This declaration set aside riparian rights and the State courts have recognized the right of appropriation for irrigation as being paramount.

UNIT OF MEASUREMENT—RIPARIAN DISCUSSION—RECENT DECISION OF STATE SUPREME COURT.

The California State Irrigation Convention of 1884 adjourned from their May meeting at Riverside to Fresno, in December of the same year. They virtually followed the advice of State Engineer Hall, and adopted a resolution making the cubic foot per second the unit of water measurement. They urged a system of record for water rights. The legislature was asked to make all the waters in natural streams and lakes "public," or people's property, to be subject to economic appropriation; to provide the extension of "the law of eminent domain" so as to allow an irrigation district to condemn and pay for rights of way, land, canals, ditches, and water claims and rights of whatever nature held by any person or corporation, or any other private rights of property, however existing or acquired, or by whatever name designated, which may be necessary for the appropriation or use of water; to provide for the annual accounting "of all waters used," and "for a proper distribution of the waters of any stream between appropriators," and so to arrange the code as to make plain the rights and duties of appropriators. There has, however, been no definite legislation, and the Supreme Court of the State has recently decided in favor of the riparian owners, thereby creating great excitement among the water appropriators of the State, who are believed to constitute the large majority of those interested as users. The riparian decision was made by four of the seven judges.

The litigation on which the decision is rendered was commenced by Charles Lux, Henry Miller, James C. Miller, and others, against J. B. Haggin, many individuals and corporations as defendants. Lux and Miller, by dismissals, became the only plaintiffs, and the Kern River Land and Canal Company the sole defendants. The suit has been prosecuted to obtain a decree enjoining the defendant from diverting the waters of Kern River, which it is alleged had flowed down a watercourse known as Buena Vista Slough, through lands of the plaintiff, and which, if not diverted, would have continued to flow. Plaintiffs appealed from a judgment in favor of the defendant and from an order denying a new trial. Title I of the decision covers a statement of the case, &c., as follows:

> Can a private corporation divert the waters of a water-course, and thereby deprive the riparian proprietors of all use of the same, without compensation made or tendered to such proprietors?

It is held: (1) That the owners of land by or through which a watercourse naturally and usually flows have a right of property in the waters of the stream. (2) This property may be taken for a public use, just compensation having first been made and paid into court. Water to supply "farming neighborhoods" is a public use, and it is for the legislature to determine whether in the exercise of the power (of) eminent domain it is necessary or expedient to provide further legal machinery for the appropriation (on due compensation) of private rights to the flow of running streams, and the distribution of waters thereof to public uses. (3) But one private person cannot take this property from another, either for the use of the taker or an alleged public use, without any compensation paid or tendered (Const., Art. 1, sec. 14). (4) Riparian owners may reasonably use water of the stream for purposes of irrigation. (5) The court below erred in rejecting certain evidence offered by the appellants.

The following points are set forth synoptically:

II. The plaintiffs are not estopped from maintaining this action by reason of their assent to certain acts of a third person—the Kern Valley Water Company.

III. While the argument *ab inconveniente* should have its proper weight in ascertaining what the law is, there is no public policy which can empower the courts to disregard the law, or, because of an asserted benefit to many persons (in itself doubtful) to overthrow the settled law. This court has no power to legislate, especially none to legislate in such manner as to deprive citizens of their vested rights.

The riparian owner's property in the water of a stream may (on payment of due compensation to him) be taken to supply "farming neighborhoods" with water. In case further legislation should be deemed expedient for the distribution of water to public uses (the private right being paid for) the validity of such further legislation is to be determined after its enactment, if its validity shall then be questioned.

IV. By the law of Mexico the running waters of California are not dedicated to the common use of all the inhabitants in such sense that they could not be deprived of the common use.

V. Upon the admission of California the State became invested with all the rights, sovereignty, and jurisdiction, in and over navigable waters and the soils under them, as were possessed by the original States after the adoption of the Constitution of the United States. Since the admission the public lands of the United States (except such as have been reserved or purchased for forts, public buildings, &c.), are held as are the lands of private persons, except that they cannot be taxed by the State, nor can the primary disposition of them be interfered with.

VI. Since, if not before, the admission of California, the United States has been owner of all unnavigable streams on the public lands of the United States within our borders, and of their banks and beds. A grant of public land of the United States carries with it the common-law rights to an unnavigable stream thereon, unless the waters are expressly or impliedly reserved by the terms of the patent, or of the statute granting the land, or unless they are reserved by the Congressional legislation authorizing the patent.

VII. This State became the owner of swamp lands described in the complaint herein, September 28, 1850.

VIII. It has never been held by the Supreme Court of the United States, or by the supreme court of the State, that an appropriation of water on the public lands of the United States (made after the acts of Congress, July 26, 1866 and 1870) gave to the appropriator the right to the water appropriated, as against the grantee of riparian lands, under a grant made or issued prior to the act of 1866, except in a case where the water so subsequently appropriated was reserved by the terms of such grant.

IX. If the decisions of the State, under the grant of 1850, do not depend upon nor are limited by the State courts with respect to controversies upon the public lands of the United States, those decisions do not enter into, nor operate upon the subsequent legislation of Congress in such manner as to require that the legislation must be construed as an attempt to deprive the State of its vested rigts.

X. The common law as to the riparian right was not abrogated by certain statutes of the State applicable to a district of country within which is included the county of Kern, nor was the State estopped by such statutes from asserting its right to the flow of a natural stream from that district to and over the lands granted to the State by the act of Congress of 1850.

XI. Section 1422 of the civil code (the rights of riparian proprietors are not affected by the provisions of this title) is protective, not only of riparian rights existing when the code was adopted, but also of riparian rights of those who acquired a title to land from the State after the adoption of the code and before an appropriation of water in accordance with the code provisions.

Neither a grantee of the United States, nor the grantee of a private person who was a riparian owner when the code was adopted, need rely for protection upon section 1422. Such persons are protected by constitutional principles. The State has reserved from her grants of land the water flowing through them, for the benefit of those who should subsequently appropriate the waters.

XII. The statute of April 13, 1850, adopts the common law of England, not the civil law, nor the ancient common law of the civilian, nor the Mexican law. In ascertaining the common law of England we may and should examine and weigh the reasoning of the decisions, not only of the English courts, but also the courts of the United States and the several States down to the present time.

XIII. The doctrine of "appropriation," so called, is not the doctrine of the common law.

XIV. Riparian rights. By the common law the rights of the riparian proprietor to the flow of the stream is inseparably annexed to the soil and passes with it, not as an easement or appurtenance, but as part and parcel of it. Use does not create the right, and disuse cannot destroy or suspend it. The right in each extends to the natural and usual flow of all the water, unless where the quantity has been diminished as a consequence of the reasonable application of it by other riparian owners for purposes hereafter to be mentioned.

XV. By our law the riparian proprietors are entitled to a reasonable use of the waters of the stream for the purpose of irrigation. What is such reasonable use is a question of fact, and depends upon the circumstances appearing in each particular case.

XVI. On behalf of the defendant certain witnesses gave testimony tending to prove that after commencement of the action and issue joined, there was no water-course, as claimed, and no channel through which the water could have flowed. The court erred in rejecting evidence offered by plaintiffs in reply, tending to prove that after dates mentioned by said witnesses for defendant there was no water-course and no channel.

XVII. The court below erred in rejecting all or some of the certificates of foreclosure offered by the plaintiffs in reply. The defendants contend that the provisions of the civil code from the time they took effect (May 1, 1872) operated to deprive subsequent grantees of State lands, intersected or bordering on streams, of all the rights known as riparian rights.

The civil code saves riparian rights to those receiving grants of State lands, subsequent to the enactment of section 1422, quoted above. Assuming this, the court below erred in excluding the certificate of purchase. For the errors mentioned in Titles Nos. XVI and XVII, a new trial should have been granted by the court below.

Judgment and order reversed, and cause remanded for a new trial.

The reasons given in the contrary opinion, written by Justice Myrick, cover the following points: The adoption of the common law of England by the act of the State legislature was not intended to and did not establish a rule of decision as to the right of appropriation of water for irrigation. The land of the birth of the common law of England had no occasion to consider or act upon the necessity for irrigation and appropriation—was not within the scheme of its laws. The plaintiffs in this case are not in position to claim an absolute right to the flow of water over or through these lands. The State proprietor initiated a system of appropriations of water. The natural result of that system, applied to the waters of Kern River, would be to reduce the body of water flowing to the lands of plaintiffs, thus measurably accomplishing the object of the grant. Lands granted for the purpose of having water drawn off have not the right attached to them to have all water flow to them which, in the course of nature, would; at least, it is not clearly so established.

Of the effect of this decision one of the plaintiff's attorneys, Mr. Haughton, is reported as saying: All the old canals in that section (Kern County) of the country run parallel with the water-courses and irrigate riparian lands, and there was no serious trouble until Haggin and Tevis built the Callaway Canal to reclaim desert land, and diverted the water from the river at right angles. In doing this they were enabled to put in 20,000 acres to alfalfa, and took water away from 200,000 acres of rich land below them. In other words, every acre they reclaimed dried out 4 acres belonging to Miller and Lux, and others. Their canal is now 85 feet wide, and has 4 feet of water flowing in it, but under this decision I suppose the canal will be closed up and the result, in that event, would be the drying out and reversion of their lands to a desert waste.

SYSTEM OF WATER DISTRIBUTION IN SOUTHERN CALIFORNIA.

There are four systems of water distribution within the irrigation region of Southern California. The oldest and most notable is that in vogue at Los Angeles. The water is owned by the municipality and distributed by public officials. The money, therefore, goes into the public treasury. The zanjero takes all orders and distributes pro rata, taking the acreage to be sowed into consideration. The objection to the plan is in the wasteful open ditches. Cement pipes would do away with most evils and ultimately pay the city well for the outlay.

The next system commonly in vogue is that of the unlimited spread of water. It is wasteful. The method is as follows: A water company is formed, with a large capital stock. A water right is secured from some river; the water is put upon land as it is settled up, and is soon spread over a large tract, without regard to economy, causing scarcity in summer, when water is most needed to save and perfect the crops.

The "prior right" plan comes next in order. It is thus described: A person or company buys a tract of land, say, 2,000 acres, and a water supply of, say, 200 inches as measured in an ordinary season in midsummer. This water-supply will furnish water to the tract of 2,000 acres on a basis of 1 inch to 10 acres. That is considered enough, and so it is in some localities. The individual or company subdivides his land and commences to sell it off. Mr. A comes along and buys a 10-acre tract. He gets a deed for the 10 acres of land and a supply of water from a certain source of water-supply on the basis of 1 inch of water to 10 acres of land. He puts his deed on record and goes to work, thinking that he has a good water right, and so he has. B comes along and buys 10 acres more on the same basis, and the sales go on at this rate until the entire 2,000 acres of land are sold and with it 200 inches of water. Under the deeds each owner of land has a right to his share of water so long as the supply remains up to the standard of 200 inches. But a dry season comes and the supply is reduced to 175 inches. Who owns the 175 inches of water? Mr. A had his deed on file first, and it calls for enough water to irrigate 10 acres of land on a basis of 1 inch to 10 acres. He evidently owns 1 inch of water. B also owns 1 inch, but his title is subject to that of A. So long as there are 2 inches in the stream B's water right is good, and so on up to the man who bought the one hundred and seventy-fifth 10 acre tract. He and those who bought prior to him each take their inch of water to each 10 acres owned, and thus the entire 175 inches of water are appropriated. What is to become of the other land owners who bought after that? They evidently have no water until the rains come again to swell the stream. There are several localities in Southern California where the water rights are on this basis.

The plan of distribution known as the "Holt system," from having been projected by Mr. L. M. Holt, editor of the Riverside Press and Horticulturist, is the one which grows in favor among the later colonies. Ontario colony seems to be one of its most favorable illustrations, and the following description is given:

> Chaffey Bros. bought certain water rights in San Antonio, one item being a half interest in the San Antonio Creek. They also purchased some 10,000 acres of land on the plain below the cañon and laid off the Ontario tract. They then formed the San Antonio Water Company, with a capital stock of 15,000 shares, and provided that this company should furnish water to owners of stock only, and that the amount of water in the possession of the company should be distributed pro rata among the stockholders. They then made a contract with the company to sell all their water rights in San Antonio Cañon to the company to conduct the waters from the cañon to a reservoir to be built near the head of Euclid avenue, in cement ditch, pipe, flume, or other viaduct; to construct the reservoir and to pipe the water from the reservoir in concrete pipes to the highest corner of each 10-acre lot to be irrigated, and to turn over all this property and water rights to the company, taking in payment therefor the stock of the company on the following basis:
>
> The waters of the company are to be measured under a 4-inch pressure at a point where they are to be emptied into the reservoir, on the 15th day of July, and stock is

> to be issued to Chaffey Bros. by the company on a basis of 10 shares of stock for each inch of water.
>
> Chaffey Bros. reserve the right for fifteen years to develop the waters of San Antonio Cañon or to furnish water from any other source that can be put into the reservoir, and for each inch of water so developed or furnished and measured on the 15th day of July, 10 shares of additional stock are to be issued in payment therefor. As Chaffey Bros. sell the land they transfer one share of stock with each acre sold, and thus, when all their stock is sold, representing the water turned over to the company and measured in midsummer, the 15th of July, they can sell no more land with water right, and hence the water cannot be spread over more land than it will irrigate. All the water belonging to the company is divided equally among the stockholders according to the number of shares held by each. In winter and spring this amount will of course be very large, and in midsummer it will average on the 15th day of July 1 inch of permanent flow to each 10-acre tract. Some seasons it may be a little more and some seasons it may be a little less at that season. If in a very dry season it does get to be less the amount on hand is divided equally, each one taking less, but all getting enough to tide over the extraordinary season. The last purchaser has just as good a water right as the first one.
>
> These systems are represented in character. Some other localities have modifications of this system. Pasadena has a system of iron pipes for distributing water under pressure from a reservoir. The North and South Fork ditches of the Santa Ana River in San Bernardino County have shares or undivided interests with no incorporation. Each owner of shares uses his pro rata of water on as much or as little land ashe thinks best.

There are four large streams of water in Los Angeles and San Bernardino Counties in Southern California, flowing from the mountains towards the sea, that furnish water for irrigating purposes. Commencing on the west we have—

(1) The Los Angeles River, that furnishes water for the city of Los Angeles and territory adjacent thereto.

(2) The San Gabriel River, that supplies water to the Azusa and Duarte settlements in Los Angeles County.

(3) The San Antonio Cañon, on the line between Los Angeles and San Bernardino Counties. This stream is equally divided, one half going to Ontario on the east, and the other half to the Loop and Meserve tract and Pomona on the west.

(4) The Santa Ana River, that furnishes water for the North and South Fork ditches, all the water that comes from the mountain cañon being taken up by these two ditches.

Beside these four principal streams there are two other considerable bodies of water, Warm Creek and Spring Brook. The first named flows into the Santa Ana 12 miles below the cañon. With other springs and smaller streams it supplies the Riverside settlements. Northwest of Riverside Spring Brook rises and furnishes another large body of water which flows down towards the sea. Most of this is taken out near the Rincon; and again other streams and springs furnish water for the river that supplies Anaheim, Santa Ana, Orange, and Tustin City with water. The San Gabriel River is perfectly dry in summer below where the water is taken out for Azusa and Duarte, but 10 miles lower down quantities of water come to the surface, and the Los Nietos country is supplied with irrigating water. The San Antonio cañon furnishes a fine stream of water that is well supplied with mountain trout.

Hon. R. M. Widney, of Sierra Madre, Los Angeles County, writes generally of that section as follows:

> The water in running streams is soft water from the rain and snow falls on the mountain. Some wells reach hard, some soft water. The cost of sinking a well, including 7-inch pipe (when not in stone), is $1.50 per foot for the first 100 feet; after that, 50 cents per foot extra is added to each new run of 50 feet.
>
> In the Los Angeles Valley there are about 300,000 acres of land, of a rich, sandy loam, where the water is from 5 to 12 feet from the surface. By cultivating the soil, keeping it free from weeds, the moisture will remain within 2 inches of the surface. All deciduous fruits do remarkably well on this class of land without irrigation.

This land really needs no irrigation for all ordinary purposes. Artesian water is to be had on this land at a depth of from 60 to 100 feet.

The next grade of land is rolling and table-land, with the surface above the water level from 12 to 30 feet. This land is a warm, rich, sandy soil, free from all except the occasional frosts. On it grow in tropical vigor the orange, lemon, lime, and other citrous fruits.

The foot-hills embrace an area of some 300,000 acres. On this the surface is from 50 to 200 feet above water. With irrigation from the mountain streams it is the highest priced land in the country.

Water right for irrigation is worth about $20 per acre on the first class of lands above described. On the second class of lands the water right is worth about $50 per acre, while on the third class of lands the water right is worth from $75 to $100 per acre. This is owing to the fact that the first class of lands needs very little irrigation. The second class, by reason of frost, is somewhat limited in its products, while on the third class of lands, with water to irrigate, the yield of fruits is superior in quality.

THE LOS ANGELES ZANJAS.

The Spanish soldiers who established the town of Los Angeles, on September 4, 1781, dug the first irrigating ditch, or zanja, from the river to their fields. This was the beginning of the present remarkable irrigation system of Los Angeles. In time it became necessary for one man to devote his whole time to the repair of the zanjas and the distribution of water, and accordingly a zanjero, or water overseer, was appointed.

The sources of water are three: first, rain; second, springs; third, wells. Under the warm sun the water in the zanjas is rapidly evaporated. The friable soil absorbs it in no small quantities. To prevent this waste, cement, or costlier iron pipes have been introduced. Further economy is practiced in the creation of large reservoirs, which are filled with the surplus of rainy days or swollen rivers, for the long dry spell. Dams are also thrown across cañons in the mountains, thus backing up and storing the waters which otherwise would be spread out upon the plains and lost. Common and artesian wells, and tunnels into the mountains, also increase the supply of water.

The Los Angeles River rises on the Encino Ranche, about 12 miles northwest of the city. Entering the city, what water is not taken out entirely sinks before reaching Seventh street. In times of very high flood the water runs down the channel of the river-bed, uniting with the Old San Gabriel River, and emptying into the ocean just west of Long Beach. At such times the river is about 35 miles long. The present channel was opened to the ocean by the freshets of 1825. Previous to that the country between San Pedro was a vast willow swamp.

The first irrigating ditch is taken out of the river 3 miles above Sepulvede station, on the Southern Pacific Railroad. It is called the main supply. It is brought down on the west side of the river. Near the city's northern limits the main-supply ditch is divided into east and west branches. The east branch is numbered 9, and the capital E is added to it to designate the east side of the river, where it goes; it is always spoken of as Zanja 9–E. In 1884 it was piped across the river at a cost of $30,000. Zanja 9–E empties into the eastern reservoir known as No. 5, that is, while it is only one of the two reservoirs the city now has, it is the fifth of a series planned by the engineers and which are being created as fast as money can be obtained. Each of these two reservoirs contain, when filled, sufficient water to carry on the regular irrigation for sixty days, or both for four months. When all six shall have been made it is calculated that they will furnish enough water for irrigation for nine months, exclusive of whatever water may be in the river, providing no more rain falls.

Reservoir No. 5 is situated over the hill at the head of Downey avenue. From reservoir No. 5, Zanja 9-R takes water to all the high table-lands east of the city. This zanja got its letter R with its number because it is taken from the reservoir.

Zanja No. 7 is taken out of the river at the Macey street bridge and supplies water to the narrow tract of land between the river and the eastern bluff. The Zanja Madre (mother ditch, probably so called because it was the first ditch of the city's founders in 1781) is taken out of the river at the toma (from the Spanish tomas, to take) just at the intersection of Buena Vista street. It runs down through the center of the city and supplies that portion. The Zanja Madre and Zanja No. 7 draw direct from the river.

Returning to the first ditch taken from the river, the western branch is called Zanja C and R, for the old Canal and Reservoir Company's ditch. It empties into Reservoir No. 4, the second reservoir now owned by the city, but the fourth in the series as planned. The water is taken from Reservoir No. 4 by Zanja 8-R and distributed over the entire western portions of the city. These ditches average 75 miles in length. Their original cost of construction was several millions of dollars, and over 8,500 acres per month for at least six months in the year are irrigated by them.

The value of the water in the river may be realized when it is known that in August, 1884, the city purchased the remaining fraction of the water it did not own of G. J. Griffith, the proprietor of the Los Feliz ranch, for $50,000. This fraction was one-tenth of the flow, estimated at 8 cubic feet per second. The city had been beaten in two suits before the Supreme Court in trying to get title to the water. The city is divided into six districts, each one of which is guarded by a deputy zanjero, at a salary of $75 per month. He furnishes himself with two horses, and is expected to be on duty day and night. He keeps the ditches in repair, divides out to each land owner his share of water, and guards against any water being stolen. As irrigation goes on night and day, his duties are arduous. The deputies are under control of the zanjero, who receives $150 per month.

The irrigating season usually begins in April or May, and lasts till November or December; indeed, there is some irrigation all the year round, even in wet weather, for vineyards, or to drown gophers. On the 24th of each month the party desiring to irrigate goes to the zanjero's office and files a written application for water, pays his money, gets a ticket, and the first convenient date is assigned to him. Here comes in the curious and perplexing measurement of water.

It is reckoned that the first main ditch takes 18 "heads" out of the river. Each of these heads equals 2 inches. Now, how much is an "inch?" The Civil Code of California (section 1415) defines a "miner's inch" as that quantity of water which will flow through an opening 1 inch square in the bottom or side of a vessel under a pressure or head of 4 inches. This has a flow of 24.56 cubic inches per second or 538.06 gallons per hour. So much for the legal definition; but when it comes to Los Angeles "heads" and "inches" they must be taken in a Pickwickian sense. Briefly described, they are as follows: When the water is taken out of the river it is called 18 heads, whether it is a large or small quantity. The heads vary, therefore, in size according to the supply of water. The main ditches are divided into small ditches; each of the latter is reckoned to have 2 heads. The tickets call for one-half of the water, or 1 head, in a small ditch for twenty-four hours, beginning either at sunrise or sunset of a certain date. Water is sold at the following rates: Inside the city limits, per day, $2; per night, $1.75; per half day, $1.75. Out of the city limits, per day, $4. One "head" is allowed to each purchaser for twenty-four hours. Vineyards and corn require irrigation three times per year; citrous trees, every six weeks.

From November 1, 1884, to November 1, 1885, the total receipts for water, fishing permits, &c., amounted to $12,415.50; expenses, salaries, repairs, and improvements of ditches was $14,437.57. There was also the additional improvement of piping Zanja 9-E across the river at a cost of $30,000. This zanja will be further piped the coming year by the connecting of the two pipes which now cross the Los Angeles River and the Arroyo Seco, at a cost of $17,000, as provided in the lately voted bonds. About 8,500 acres altogether, inside and outside the city, were irrigated the last season. With the proposed piping and storage, engineers estimate that four times the present area can be irrigated. This is all outside of the private work of supply done by three water companies. The foregoing account is mainly condensed from a paper published in the Los Angeles Herald. Many efforts were made to obtain official data, but no responses of importance were obtained.

CESSATION OF ARTESIAN WATER.

A curious question of property rights has arisen in San Bernardino County. For years the district around the old town of San Bernardino has been supplied with water from artesian wells, but recently settlers on lower ground adjacent to Riverside have commenced boring wells and tapping the same source of supply as the San Bernardino wells. In consequence, most of the latter are showing signs of exhaustion, while some of them have already ceased to flow. This is a serious danger to the San Bernardino settlers. There are in California several thousand flowing artesian wells, and in some localities the prosperity or even the habitableness of the country is dependent upon them. In every region where the old wells can be exhausted by boring in a different place and tapping the subterranean stream at a lower level the property is in danger of extinction.

OBSERVATIONS ON THE EFFECTS OF IRRIGATION.

The following statements were made at the meeting in 1884 of the San Joachim (Cal.) Viticultural District Convention, the parties being leading vineyardists of that region:

Mr. HARASZTHY. Do you find it necessary to irrigate during the year?

Miss AUSTIN. That depends altogether on the locality.

Mr. HARASZTHY. I mean for Fresno vineyards.

Miss AUSTIN. For our section of Fresno I have found from my experience that we can lay down no law that will apply to all cases. I have found with our depth of soil, however, and with our yield, we need no summer irrigation for grapes. We irrigate in winter but once, this last winter not at all. I generally flood the vines once, giving them a thorough flooding.

Mr. HARASZTHY. How deep have you to dig for water?

Miss AUSTIN. I have not dug lately, but my neighbors say from 7 to 8 feet.

Mr. HARASZTHY. What amount of water do you use?

Miss. AUSTIN. Water is abundant and we flood one check after another. The water will stand on a check, say to the depth of 2 or 3 inches.

Mr. WETMORE. That means how many inches of water?

Miss AUSTIN. I could not tell you, I don't know; I never measure it, I never have measured it, it just flows through the gate. Until two years ago we watered in summer, also irrigated, but the country has filled up so long by seepage that it is unnecessary, and I think the time will come when it will not be necessary to irrigate even in winter. I don't think it is necessary now, in some places.

Mr. HARASZTHY. What are your views on irrigation, Mr. White, based on your practical experience?

Mr. WHITE. So far as irrigation is concerned, this country for the past five, six, or seven years has changed wonderfully. When I first came here, in digging a well we went down 45 feet through the dry dust. There is a man who lives about a mile from my place who says he got water 4 feet from the surface. I am satisfied that where the water is as near the surface as that, there is no need to irrigate summer or winter. The effect of irrigation in summer would be to damage the grapes, unless they were suffering for want of moisture. As long as they are growing, don't put water on them but keep cultivating them.

Mr. HARASZTHY. Could you get along with this soil and in this climate without summer irrigation when the water is 40 feet from the surface?

Mr. WHITE. No, I would say it has been necessary up to within the last year or so to summer irrigate two or three times in order to keep vegetation alive. In fact, I have an apricot orchard in blue soil that needed it this year.

Mr. HARASZTHY. I will state that I am interested in a vineyard in Yolo County, and last year there the thermometer stood 120° F. in the shade. The vines are some twenty-eight years old now. We have dug down in some low places and found it to be about 60 feet to water. We never had a drop of water on that vineyard except by our regular rainfall, and the vines are quite thrifty. They don't bear what yours do, but good wine is made from them.

Judge North, of Fresno, commenting on Mr. White's testimony, said:

The experience of Mr. White has been, that for years he was not able to do what he is doing now. When it was 45 feet to water he had to irrigate in summer, but when the water comes up to within 6 or 8 feet of the surface he can get along better without water, and it is not desirable to irrigate. Every year brings up some new question, produces some new conditions, and a rule that will hold good this year will fail next.

IDAHO.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.*

H. C. Riggs, Falk's Store, writes:

Payette Valley is in Ada County. Falk's Store is the post-office. The valley is 30 miles long by 3 wide. All the land on the Payette River is taken, and there are many claims on the back tier. These are called sage brush ranches. The average ranch is 160 acres, but some go as high as 400 to 700.

A. Rossi, postmaster at Washoe, writes:

We are located between thirty-ninth and fortieth degrees of west longitude and near the forty-fourth of north latitude. Railroad is from Granger, Wyo., to Huntington, Oreg., between the post-offices of Payette, Idaho, Ontario, Oreg., and Falk's Store, Idaho, on the southeast. Area, 38 square miles, of which about 4,000 acres are bottom land, 12,000 acres upland, and 8,000 acres hilly. First settlements made in 1870, when the locality was used for wintering stock; sizes of farms from 80 to 320 acres.

James A. McGee, secretary Phylles Land Company, of Caldwell, Ada County, writes:

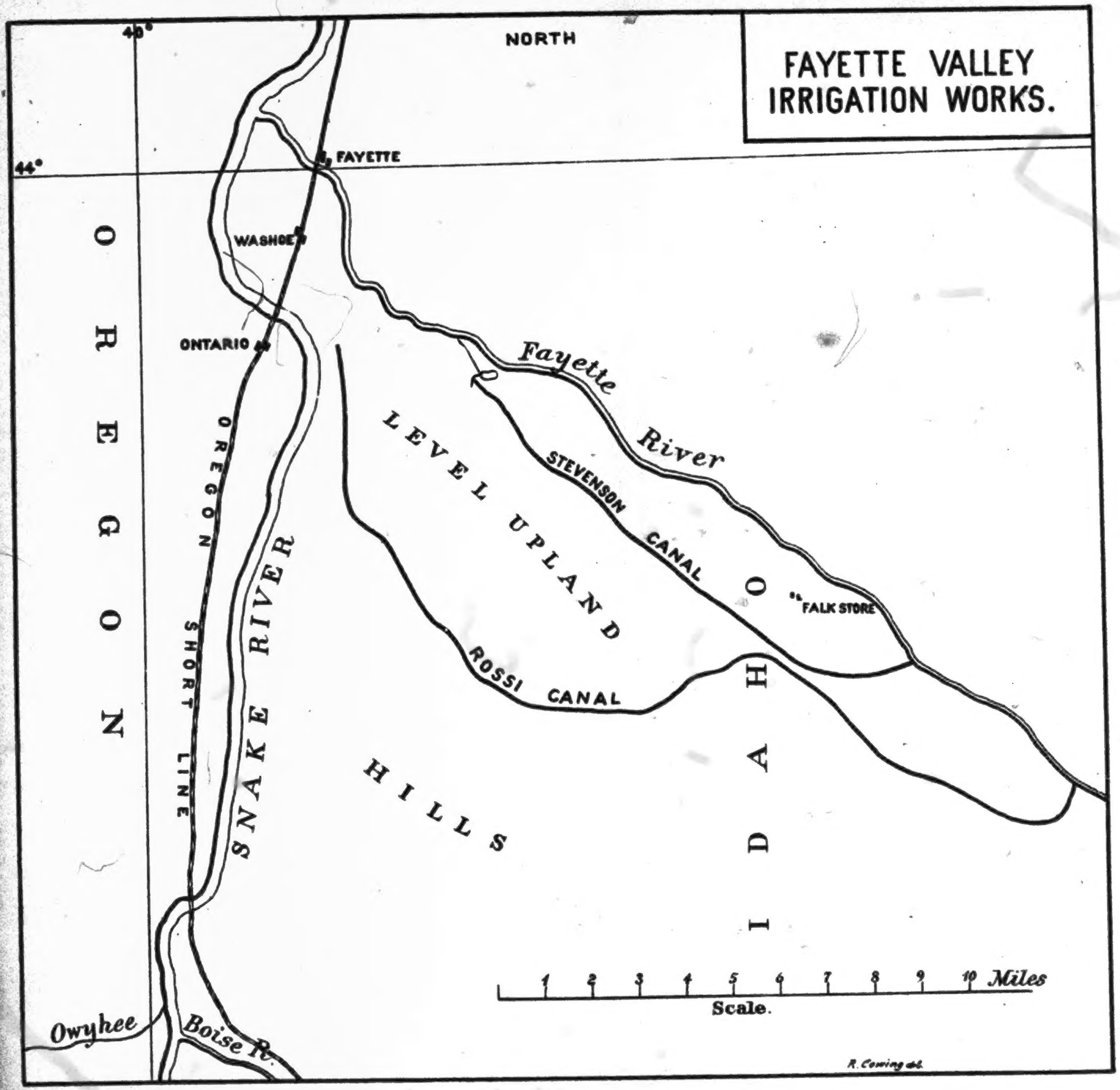
Our nearest post-office at present is Caldwell, Ada County. Our railroad station is called Nampa, which is the proposed name of this place. Lands in the immediate vicinity capable of irrigation amount to about 200,000 acres; about 40,000 acres are now held by actual settlers; average size of farms, 160 acres to each settler.

(2) *Original value of land per acre, present selling price; state if the purchase of land carried water also; if not, rent or price of latter per acre.*

James A. McGee writes from Caldwell:

Original value of the land was $1.25 per acre. Present selling price is from $10 to $60 per acre, according to improvements. Purchase of land does not carry water with it only in isolated cases. Price of water at present is $1 per inch yearly rental, and $8 per inch for perpetual right.

FAYETTE VALLEY IRRIGATION WORKS.


40°
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A. Rossi, postmaster, Washoe, writes:

The original value of land was $2.50 per acre; the present selling price in large quanties is from $20 to $30 per acre; small sales from 8 to 10 acres, close to railroad, from $30 to $75 per acre, water included; rent of water per acre, $1.

H. C. Riggs, Falk's Store, writes:

The land ranges from $7 to $20 per acre. Most of the river ranches have private ditches which go with the sale of land. Three large ditches or canals have just been completed, but there is no settled price for water as yet.

(3) *Products of land; amount market and average value of crops; how long planted. Are fruits grown?*

H. C. Riggs, Falk's Store, writes:

Wheat yields 30 bushels per acre; oats, 40 to 50; barley, 40; rye, 30 to 40. All the hardy vegetables grow in great profusion, and the same with fruit.

Owing to the dryness of the climate our fruit matures in the finest condition, and keeps well.

Grain is selling at $1.25 per cental; hay, $7 to $10 per ton; potatoes, 1 cent per pound.

A. Rossi, Postmaster, Washoe, writes:

All kinds of grasses, cereals, vegetables, and fruits. Average crops per acre: Four hundred bushels potatoes, 30 of wheat, 50 of oats and barley, 2½ tons of timothy, 3 of red top, and 5 of clover; the latter is cut twice. Value per pound: Wheat, 1 cent; oats and barley, 1½ cents; potatoes, ½ cent; cultivated since 1872. A crop of apples, pears, peaches, and plums was gathered from a few trees that were planted in 1882; first trees planted in 1882.

James A. McGee writes from Caldwell, Ada County:

Hay, vegetables, corn, oats, wheat, barley, and rye; mostly hay and grain.

Grain produces from 35 to 50 bushels per acre, hay about 2 tons per acre, valley lands admitting of three cuttings; potatoes and turnips, about 10 tons per acre. Grain brings from 1 cent to 1¼ cents per pound; hay, $6 to $10 per ton; vegetables, from 1 to 2 cents per pound. Plenty of fruits grown, and production and quality are number one.

(4) *Extent of irrigation works and their character; source of supply, method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

James A. McGee, secretary Phylles Land Company, Caldwell, writes:

Two ditches, capacity 75,000 inches, drawn from Boisé River, distributed by boxes in main ditches. Not finished, estimated to cost $300,000; $75,000 already expended; can get 200,000 inches of water if necessary. One inch of water supplies 1 acre. Ditches are about 45 miles long, running from Boisé River to Snake River. The land capable of irrigation amounts to at least 400,000 acres. The farms are mostly under cultivation, but cattle are raised in the vicinity on all sides. The ranges are very good.

H. C. Riggs, of Falk's Store, writes:

The three irrigating ditches of Payette Valley will cover most of the land on the south side of the river—they are taken out of the river. I have no correct data at hand, but I should judge that the three cost $150,000. There is a canal surveyed on the north side, and the company say they will construct it. It will cover a higher body of land and better soil. [See diagram.]

(5) *Climatic conditions, temperature and rainfall; results of observations, if any, as to the influence of irrigation on moisture of earth or sky; effects of irrigation on health, fertility of soil, &c.*

James A. McGee writes:

The mean annual temperature for the year 1885, was 52° F. Range in temperature from 7° below zero (January 1) to 99° above (June 28). There were twenty-four days in the summer months on which the thermometer registered above 90°, and in the winter months sixty-two days on which the mercury fell to 32°. Total annual precipitation, 12.56 inches, of which six-tenths of an inch fell between July 1 and September 30. Idaho having the lowest death rate (0.33) of any State or Territory of the Union, it is presumed that the effects of irrigation on health are not in any manner injurious. The fertility of the soil is enhanced one hundred fold by irrigation.

H. G. Riggs, of Falk's Store, writes:

For the past winter the mercury has never been below 5° above. The average has been 20° above. Now, January 27, 50° above. However, this is rather a mild winter. We have spring and fall rains regularly, but seldom have any in summer. Many old orchards want no water since the trees have shaded the ground. I am of the opinion that irrigation is conducive to health, except where the foilage is allowed to grow too dense around the dwellings. This is already the case in Boisé City, but they are cutting it away to give the sun a chance to shine.

EFFECTS OF IRRIGATION.

Mr. A. Rossi, postmaster at Washoe, writes as follows:

No observations have been made in this locality regarding the effects of irrigation, but in Boisé Valley, near Boisé City, first settled in 1863, about 50 miles southeast from here, and 150 feet higher above sea level, no moisture could be found in the atmosphere in summer of 1871 and preceding periods, while at present the moisture is very perceptible, dew being noticed on plants, &c. Irrigation does not seem to affect the health of that community, but reduces the temperature by an average of 10°. Previous to 1872 the mercury generally reached 110° in the shade, while at present it never reaches over 100°.

Low or bottom lands are irrigated by plowing small ditches the whole length of the field, 8 or 10 feet apart, and letting the water run through them about once every ten days. In irrigating uplands the soil containing no sand, therefore being less subject to percolation, the water is run over the surface of the ground in sections of from 10 to 25 acres, according to the evenness of the land. A man lets on from the main ditch a stream of water containing from 100 to 200 inches, follows the water up, builds little dikes in places where it is liable to cut the soil, or where he finds depressions in the land, leads the water to the highest places in that portion of the field, and generally assists the water in covering the whole piece of ground. At night he turns off about half the stream and lets the balance do its own work. It requires 1 inch of water, running at a speed of 2 feet per second, to irrigate 1 acre. One canal, not completed, is to be 20 miles in length; capacity, 12,500 inches. The expenditure has been $16,000; $15,000 more will be required to complete the work. There is one canal completed by Hon. E. A. Stevenson. It is 14 miles in length and cost $12,000. Its capacity is 5,000 inches. Source, Payette River. The uplands will be covered by the two canals.

Our climate is dry in summer, the rainfall being from 8 to 14 inches. We have rain and snow in winter, but little precipitation in fall or spring. The average winter temperature, 25°; that of summer, 80°. The lowest temperature is 20° below zero in winter, and 50° above in summer. The highest is 60° above in winter, and 110° above in summer.

LIST OF IRRIGATION COMPANIES.

The following list of land and water companies organized in the Territory, with the location of their principal offices and the names of their officers, is furnished to the Department by the Hon. E. H. Stevenson, governor of Idaho:

The Alturas Water Company, Hailey, Alturas County; trustees, W. T. Riley, Texas Angel, *et al.*

The Bellevue and Wood River Ditch Company, Bellevue, Alturas County; trustees, J. H. Harris, C. H. Clay, *et al.*

The Boisé City Water Company, Boisé City, Ada County; trustees, John Lemp, C. Jacobs, *et al.*

The Boisé Valley Irrigation Ditch Company, Boisé City, Ada County; trustees, D. Heron, S. D. Aiken, *et al.*

The Beaver and Potosi Ditch and Water Company, Myrtle, Shoshone County; trustees, John Herrmann, James F. Wardner, *et al.*

Boisé City Canal Company, Boisé City, Ada County; trustees, J. P. Wilson, George Davis, *et al.*

The Boisé Valley Irrigation Ditch Company, Boisé City, Ada County; trustees, E. P. Baker, Reuben Cox, *et al.*

The Bingham County Agricultural Association, Eagle Rock, Bingham County; trustees, S. F. Taylor, W. E. Wheeler, *et al.*

The Boisé, Deer Flat and Snake River Canal Company, Caldwell, Ada County; trustees, C. H. Reed, J. E. Meacham, *et al.*

The Cub River and Warm Creek Canal Company, Sand Ridge, Oneida County; trustees, Nahum Porter *et al.*

The Cedar Buttes Irrigating Company, Cedar Buttes, Oneida County; trustees, J. C. Fisher *et al.*

The Cub River and Middle Ditch Irrigating Company, Franklin, Oneida County; trustees, James Packe Franklin *et al.*

The Clifton Irrigating Company, Clifton, Oneida County; trustees, E. H. Hooker *et al.*

The Central Park Irrigating Ditch Company, Ada County; trustees, M. F. Fowler *et al.*

The Chadville Irrigating Ditch Company, Chadville, Oneida County; trustees, Stephen Allen *et al.*

The Cottonwood Irrigating Company, Cottonwood, Bear Lake County; trustees, Alfred Sparks *et al.*

The Cub River Irrigating Company, Franklin; trustees, F. M. Stephens *et al.*

The Deep Creek Curlen Valley Irrigating Company, Malad City, Oneida County; trustees, Joseph Robbins *et al.*

The Dixie Ditch and Irrigating Company, Boisé City, Ada County; trustees, J. B. Wright, M. D., *et al.*

The Dry Creek Ditch and Irrigating Company, Ada County; trustees, J. Q. Smith *et al.*

The Eagle Rock Water Works Company, Eagle Rock, Bingham County; trustees, J. M. Clifford, J. M. Bennett, *et al.*

The Eureka Ditch Company, Caldwell, Ada County; trustees, G. W. Snodgrass, C. R. Smith, *et al.*

The Emmetsville Irrigating Ditch Company, Emmetsville, Ada County; trustees, James T. Davis, Freeman S. Page, *et al.*

Eastern Idaho Mining and Water Company, Blackfoot, Bingham County; trustees, Watson N. Shilling, P. J. Anderson, *et al.*

The Egin Irrigating Company, Egin, Oneida County; trustees, William Caxson, W. M. Parker, sr., *et al.*

Eureka Water Company, Caldwell, Ada County; trustees, E. Frost, William A. Simpson, *et al.*

The Eagle Rock and Willow Creek Water Company, Eagle Rock, Bingham County; trustees, George F. Heath, Henry W. Keifer, *et al.*

The Franklin Irrigating Ditch Company, Middletown, Ada County; trustee, Lewis F. Cook *et al.*

The Georgenson Irrigating Ditch Company, Weston, Oneida County; trustees, Neils Georgenson *et al.*

The Garden Creek Irrigating Ditch Company, Garden Creek, Oneida County; trustee, William Jenkins *et al.*

Idaho Land and Irrigation Company, Boisé City, Ada County; trustees, A. H. Boomer, John Hailey, *et al.*

Idaho Ditch Company, Boisé City, Ada County; trustees, Barrett Williams, Robert M. Allen, *et al.*

The Idaho Agricultural Park Association, Boisé City, Ada County; trustees, John Hailey, John Earley, *et al.*

The Idaho and Oregon Land Improvement Company, Denver, Colo.; trustees, William G. Case, Robert E. Strahorn, *et al.*

Idaho Mining and Irrigation Company, New York City, N. Y.; trustees, George A. Pope, C. H. Tompkins, *et al.*

The Lower Payette Ditch Company, Emery School House, Ada County; trustees, S. M. King, David Garric, *et al.*

The Lemhi Valley Milling Company, Salmon City, Lemhi County; trustees, Robert Dunlap, George Steel, *et al.*

The Murray Water Company, Murray, Shoshone County; trustees, E. H. Moffit *et al.*

The Middletown Water Company, Ada County; trustees, J. Brumback *et al.*

The Middle Valley Irrigating Ditch Company, Middle Valley, Washington County; trustees, Lee Ross *et al.*

The Middleton Canal and Irrigation Company, Ada County; trustees, Hawkins Shelton *et al.*

The Malad Valley Artesian Well Company, Malad City, Oneida County; trustees, H. W. Smith *et al.*

The Malad Irrigating Company, Malad City, Oneida County; trustees, Henry Peck, *et al.*

The Ovid Agricultural and Irrigating Company, Ovid, Bear Lake County; trustees, T. C. Peterson *et al.*

The Oakley and Lower Goose Creek Canal and Irrigating Ditch Company, Cassia County; trustees, H. M. Thatcher *et al.*

The Oneida Reservoir and Irrigation Company, Oneida County; trustees, Joseph W Morgan *et al.*

The Preston and Montpelier Irrigation Company, Paris, Bear Lake County; trustees, John Bagley *et al.*

The Pierce and Cox Irrigating Ditch Company, Boisé Valley, Ada County; trustees, John W. Pierce *et al.*

Rushville Irrigation Company, Rushville, Oneida County; trustees, W. C. Davis, Nelson Carlson, *et al.*

Raft River Land and Cattle Company, Salt Lake City, Utah; trustees, W. S. McCornich, Thomas Keogh, *et al.*

The Sublett Creek Irrigating Company, Sublett Creek, Oneida County; trustees, John S Smith, John Galliher, *et al.*

The Saint John Irrigating Company, Saint John, Oneida County; trustees, Charles Dunander, Thomas Stephens, *et al.*

The Samaria Lake Irrigating Company, Muddy Creek, Oneida County; trustees, A. C. Hoskins, Joseph Harris, *et al.*

The Shoshone Water Works Company, Shoshone, Alturas County; trustees, E. C. Helfrich, J. M. S. Hickey, *et al.*

The Settlers Ditch Company, Boisé City, Ada County; trustees, R. M. Purdam, Fremont Wood, *et al.*

The Thomas Fork Irrigating Company, Webster's Rancho, Bear Lake County; trustees, Constant Webster, Lee Hart, *et al.*

Valley Water Works Company, Ketchum, Alturas County; trustees, J. J. Lewis, T. E. Clohecy, *et al.*

Weston Smith Field Irrigating Company, Weston, Oneida County; trustees, Henry Gassman *et al.*

Wood River Ditch Company, Bellevue, Alturas County; trustees, John H. Harris *et al.*

Weiser Water Company, Weiser City, Washington County; trustees, J. M. Hart *et al.*

The Wood River Land and Irrigation Company, Hailey, Alturas County; trustees, Edwin C. Coffin *et al.*

The Warm Creek Irrigation Company, Oneida County; trustees, William Nealy *et al.*

The Weiser City Water, Ditch and Irrigating Company, Weiser City, Washington County; trustees, S. M. Jeffreys *et al.*

The Weiser Canal and Irrigation Company, Washington County; trustees, Frank Harris *et al.*

The Weston Irrigating Company, Weston, Oneida County; trustees, A. W. Thompson, R. Campbell, *et al.*

EASTERN OREGON.

This portion of the State of Oregon is within the dry area, but as yet irrigation is almost unknown. The principal industry is that of stock raising.

The replies attached show how little progress has yet been made in agriculture proper.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present, any facts bearing thereon; also size of colony, farms, and ranches.*

Daniel Chaplin replies:

The location is Grande Ronde Valley, Union County, Oregon; post-office address, La Grande, Oreg. This is a private enterprise. The area is 3,000 acres, located centrally in this valley. Originally this was a sandy alkali plain, level, but too dry to be productive. Since irrigation was introduced it has not yet been cultivated in agricultural crops, but used as range for pasture. It is all fenced with barbed wire; we shall cultivate next year.

I. K. Romig, C. E., La Grande, Oregon, replies:

Our location is townships 16 and 17 in Baker County, Oregon; the post-office is Ontario, Oreg. The area is 5,000 acres. There are six owners, each controlling 600 to 1,100 acres.

C. M. Foster, C. E., replies:

Location is Baker County, Oregon; in the extreme eastern portion of the State. The area is 11,000 square miles. There are no colonies.

(2) *Original value of land per acre, present selling price; state if the purchase of land carries water also; if not, rent or price of latter per acre.*

Daniel Chaplin replies:

From Grande Ronde Valley, Union County, Oregon; that the original value was nothing; present selling price, $7 per acre; water goes with the land, water rights being permanent.

C. M. Foster, C. E., writes from Baker County:

The original price of land was $1.25 acre. Present price, according to location, is from $4 to $25 per acre. Purchase of land carries all water rights pertaining thereto.

A. W. Gowan, Joseph, Oregon, writes:

The original value was about $1.25; value of improved land from $4 to $12.50 per acres; it does not include water ditches as a rule.

(3) *Products of land; amount, market, and average value of crops; how long planted; ar fruits grown?*

C. M. Foster, C. E., of Baker County, replies:

Wheat gives 20 to 60 bushels per acre; barley the same; oats, 30 to 100 bushels; potatoes, 200 to 600 bushels. We depend chiefly on a home market. Value of grain from 1 cent to 1¼ cents per pound. But little fruit raised, except small fruits.

(4) *Extent of irrigation works and their character; source of supply and method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works; land areas, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

Daniel Chaplin, from Grande Ronde Valley, Union County, says:

Our irrigating canal is 8 miles long; water is taken out of Grande Ronde River at Orodel, and passes through improved farms, which farms use but little water, as they are naturally moist enough, but the tract irrigated is in center of valley slightly elevated, and of a dry nature.

C. M. Foster, C. E., Baker County, replies:

Every farmer owns his own ditches and water rights. Water supply from streams distributed by ditches; value of ditches in the county, $100,000. One hundred inches of water will irrigate 160 acres of land. Nine-tenths of all the land is used for pasture. There are in the county 200,000 cattle, 150,000 horses, 125,000 sheep.

(5) *Climatic conditions, temperature, and rainfall; results of observations, if any, as to the influence of irrigation on moisture of the earth or sky; effects of irrigation on health, fertility of soil, &c.*

C. M. Foster, C. E., writes:

Climate dry and warm; no rain during summer months; summer heat as high as 110°, while in winter the mercury falls as low as 10° below zero. Irrigation has no perceptible influence on health, and this is the only tract needing irrigation in this valley, which is 30 miles long by 15 miles wide; it is situated in the Blue Mountains, Eastern Oregon.

A. W. Gowan, of Joseph, says:

We have sufficient rains and snow fall through the fall, winter, and spring seasons to supply the soil with moisture through the summer drought and insure certain crops every year. Irrigation injures our soil in this and the Grande Ronde Valleys. We usually have showers of rain through the summer season; ordinarily temperate climate. Four or five days in mid-winter the mercury ranges from zero to 12° or 14° below.

In mid-summer there are five to seven days when the temperature ranges from 90° 106°.

I. K. Roomig, civil engineer, La Grande, writes of the canal there:

This enterprise, the Grande Ronde Canal, contemplates the reclaiming of 5,000 acres of land by a ditch taken out of the Malheur River. The length of ditch will be between 12 and 14 miles; capacity, 5,000 inches under a head of 4 inches. It is not supposed that 5,000 inches will be required for this enterprise, but as the ditch will cover some 3,000 acres of other lands requiring water for irrigation, it is intended to sell to others such water as they require.

The estimated cost is $5,000 for main ditches. Water will be conveyed in small lateral ditches on to each 40 acres of land. The formation of the country allows us to run the main ditch on the west side of the land and at an elevation slightly above most of it. All lateral ditches will run north and northeast from the main ditch. This work will be done in the summer of 1886. The land is covered with sage brush and a sandy soil in some places resembling an ash heap mixed with sand. With irrigation the soil will produce grain, such as oats and barley, with vegetables and fruits, including apples, pears, and peaches; but it is especially adapted for alfalfa clover (in the estimation of the owners).

There are some 200,000 acres adjoining, used as range for stock; it will not produce agricultural crops without irrigation, and is too rolling to be irrigated by any of the present methods; also too high above the water in streams.

MONTANA.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.*

William J. McCormick writes:

Missoula County, Montana, lies in the northwestern portion of the Territory. Its entire area is drained by the waters of the Columbia River and its tributaries. The arable lands constitute about one-third. The size of average farms is from 80 to 640 acres. Missions were established in this part of Montana by the Jesuit fathers as early as 1837, and white settlers began to come in as early as 1850. The non-arable portion of the land is mountainous, covered with a heavy growth of pine, fir, tamarack, and spruce timber.

Hon. William B. Webb, secretary of the Territory, quotes from Henry W. Rowley, of Billings, as follows:

Our colony is located in the Yellowstone River, in Yellowstone County, Montana. The principal town and post-office is Billings. The colony is located in what is known as Clark's Fork Bottom, being a strip of bottom land 35 miles in length, varying in width from 1 to 10 miles, and containing 75,000 acres. Nearly all the settlers have located here since the advent of the Northern Pacific Railroad, four years ago. Population of Bottom at present, 2,500. Most of the colony farms contain 160 acres.

(2) *Original value of land per acre; present selling price; state if the purchase of land carries water also; if not, rent or price of latter per acre.*

Hon. William B. Webb writes:

The land was originally only useful for grazing purposes, and was worth about 50 cents per acre for the whole season.

William J. McCormick writes from Missoula:

Titles to lands were and are acquired under the homestead and pre-emption laws. Improved farms are worth from $10 to $25 per acre. The purchase of land carries with it the right to use water from the mountain streams.

(3) *Products of land; amount, market, and average value of crops; how long planted? Are fruits grown?*

William J. McCormick, Missoula, writes:

Wheat, oats, barley, corn, rye, potatoes, turnips rutabaga, parsnips, cabbage, tomatoes, squashes, melons, cucumbers, apples, pears, plums, cherries, and all the smaller fruits are grown here. The average yield per acre is as follows: Wheat, 30 bushels; oats and barley, 75 bushels; rye, 40 bushels; potatoes, 300 bushels. From 60 to 100 bushels of wheat have been raised upon a single acre of land. All crops are raised by irrigation.

Hon. William B. Webb sends this information from Henry W. Rowley, engineer in charge of irrigation works at Billings:

Wheat, oats, corn, potatoes, and all garden vegetables, can be grown here in abundance. Wheat yields from 30 to 40 bushels, and the rest in like proportion. Oats are worth on an average 50 cents per bushel. Potatoes 50 cents per bushel. Fruits of the smaller varieties are grown easily, and larger varieties can be raised.

(4) *Extent of irrigation works and their character; source of supply; method of distribution cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas, irrigable or non-irrigable occupied for cultivation, used for cattle and sheep, &c.*

Henry W. Rowley, engineer of irrigation works, Minnesota and Montana Land and Improvement Company, Billings, replies:

The bottom is irrigated by a system of ditches which take the water from the Yellowstone River, the largest one being 40 miles in length, 30 feet broad, and 4 feet deep. About $120,000 have been spent in this bottom to prepare for irrigating the land, and there are now, 60,000 acres, covered by ditches. The land is used principally for raising hay and grain. Cattle and sheep are grazed in the hills further back from the river.

William J. McCormick, writing from Missoula, says:

We have no irrigating works. The process is simply tapping some mountain stream with a main ditch and distributing the same by smaller ditches where needed. Land thus irrigated is planted in grain, vegetables, timothy, clover, red top millet, &c.

(5) *Climatic conditions, temperature, and rainfall; results of observation, if any, as to the influence of irrigation on moisture of the earth or sky; effects of irrigation on health, fertility of soil, &c.*

Henry W. Rowley, engineer, anwers:

The climate at Billings is exceedingly mild for this latitude; we get an abundance of rain during May and June, but dry during the balance of the year. No perceptible effects as yet from irrigation on the atmosphere. Irrigation has a marked effect on the fertility of the soil, the oldest land raising much the best crops. The climate for health could not be beaten.

James Fergus, of Fort Maginnis, writes:

It has been settled only a few years. What little farming is done so far is on land irrigated by the small streams that head in the mountain ranges. Very little of the bench or upland is fit for cultivation, and, on account of want of a market for grain, no effort has yet been made to cultivate and irrigate it on a large scale. Some effort has been made to grow fruits, particularly the hardier variety of apples, but they were nearly all killed last winter, not by the frost, however, so much as because the soil was too dry when it froze up. Experience has taught us, in this dry climate, that orchards must be thoroughly saturated in the fall to preserve the life of the trees during the winter.

William J. McCormick writes from Missoula:

It would be difficult to find in any latitude upon the American continent a climate superior to that of Western Montana. As to temperature, I may give you an instance. From the 7th of February, 1885, to the 16th of January, 1886, the mercury did not reach zero. This is latitude 46½, and at an altitude of 3,100 feet above sea level, challenges comparison with any other section of the continent. Irrigation has no perceptible effect upon the earth or sky, nor in any manner does it affect the sanitary condition of the climate. It fertilizes the soil by depositing sediment down from the mountain slopes during the gradual melting of the snows under the warming influences of the sun, in the months of June and July, the season of promoting vegetation by irrigation.

NEVADA.

There are no replies to the Department circulars, but reports made in 1885 indicate that the agricultural products of Nevada are sufficient for home consumption. At the Truckee meadows, and in Mason Valley, irrigation has already put farming operations on a solid foundation. Along the entire line of the Humboldt Valley its effects are seen. The chief of the Piutes cultivates successfully a farm of 160 acres.

At Lovelock's, in Northern Nevada, 50,000 acres are occupied, and about 9,000 are now in a state of high cultivation. During the year named there were over 50,000 acres cultivated in wheat and barley, 100,000 acres in hay, 2,000 acres in potatoes, yielding annually 60,000 bushels of the finest quality, while oats, rye, corn, and all cereals and vegetables peculiar to the temperate zone are grown in large quantities. Besides this fruits are raised in many parts of the State, and yield abundantly. As a pastoral region Nevada promises to be unsurpassed. The estimated number of cattle is 700,000; of sheep, 300,000; and of horses, 70,000 head.

WYOMING.

Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.

A. C. Beckwith, Evanston, Uinta County, writes:

My desert-land claim is located about 50 miles in a northerly direction from Evanston, Uinta County, Wyoming, and contains about 640 acres.

Hon. M. F. Benefiel, Big Horn, says:

Our farms are located on the headwaters of Little Goose Creek, and our ditch is constructed to carry the water from Hurlbut Creek (one of the tributaries of Little Goose Creek) to our farms. We have an incorporated company, and have a 400-inch water right recorded. Present value of ditch and water right is about $800.

Thomas Sturgis, Cheyenne, writes:

The land and irrigation works of the Wyoming Development Company are situated 60 miles north and slightly west of the town of Cheyenne, in Laramie County.

The office of the company is in Cheyenne; post-office address of superintendent, on the lands, Bordeaux, Wyoming. The lands eventually to be irrigated will approximate 50,000 acres, and sufficient water can now be furnished colonists, but no settlements have yet been made, the irrigation works being but just completed.

Original value of land per acre; present selling price; state if the purchase of land carries water also; if not, rent or price of latter per acre.

A. C. Beckwith, Evanston, writes:

I suppose land was originally worth the Government price of $1.25 per acre, and it has cost about $8 per acre to reclaim it.

Thomas Sturgis writes:

Original value $1.25 per acre. None sold as yet. Land will probably be sold by itself on several years' time at low interest. Water will be rented according to acreage farmed by each settler from year to year. Rate of water, $1 to $1.25 per acre per annum for land farmed.

M. F. Benefiel, Big Horn, Johnson County, writes:

The length of main ditch is about 2½ miles. The stream is supplied with water from the melting snow in the mountains. There is the most water in the latter part of

May and the least in September. The amount varies from about 75 inches to about 400 inches. This helps to water 480 acres of land, but is not sufficient to irrigate properly more than one-third of that amount. There are several thousand acres in this locality which might be made valuable if there were sufficient water for it.

Extent of irrigation works and their character; source of supply, method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works; land area, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.

Thomas Sturgis, Cheyenne, writes:

These irrigation works are probably the largest in the country, and have been very costly; $250,000 have been already expended. The principal features are a rock tunnel, 3,000 feet long and 8 by 7 feet in diameter; one canal 23 miles long, 32 feet in width at top, and 27 feet at bottom. Another canal of nearly similar dimensions and lateral canals of proportionate extent and size are in use. The sources of supply are the Laramie River and Saville Creek. It is thought the present main works, with additional laterals, will fully supply the lands. Probably four-fifths of the lands can be irrigated and used for farming. The remainder can be grazed. The average rainfall is light—12 to 15 inches. Temperature, winter, from —20° to 40° above; summer, 50° to 80°. Natural moisture entirely insufficient for any agriculture. Good degree of fertility developed by artificial irrigation. No statistics as to health or as to increase of rainfall by surface irrigation. The lands will produce all small grains and grasses which can endure the winter temperature of this latitude (41 degrees), and of this altitude (5,000 feet). Wheat, oats, barley, and alfalfa do well. No fruits have been tried. Some small tracts have been sown with wheat and oats, but none marketed. Distance from railroad (60 miles) will affect values materially.

Our enterprise is the first organized and extensive effort in this Territory to reclaim a sufficient tract to support a farming community. The want of an agricultural interest is greatly felt. All cereals are now imported. The streams which supply enough water for any important amount of land are very few and far apart. They flow frequently for many miles through inaccessible cañons. The expense of getting the water out of its natural bed is great, and owing to the volume of water which pours from the mountains in the spring, the dams must be built by skillful engineers and of great strength and proportionate cost. Owing to the broken nature of the country it is rare to find any considerable body of land at a suitable level and of such comparative smoothness as to repay the expense of getting water on to it. This fact has prevented, and will continue to prevent, any great number of enterprises like that of this company. It is seldom that so large an amount of money can be drawn into an enterprise which at the best is a doubtful one, offering in any event very moderate returns; and the proportion of land throughout this Territory which combines the necessary conditions, and which can at the same time be reached by canals the supplying stream of which is sufficiently prominent and powerful for the wants of the lands, is very small indeed. The work of the Wyoming Development Company has been conducted on strictly business principles, every dollar of outlay and expenses being supplied in actual cash. While its result must be of vast benefit to the community at large, it is quite probable that the chief return to the promoters of it will be of an indirect character.

Hon. S. W. Downey, of Laramie, writes the Department as follows:

The southern part of Wyoming is watered in part by the Big and Little Laramie Rivers and their tributaries. But a small amount of land along the margins of the streams receives any benefit, as the most of the land is in a barren or desert condition, and must be irrigated to produce crops. Irrigation has been carried on for some ten or twelve years on a limited scale, but more interest has been awakened on this subject recently. The Pioneer Land Company about five years ago began the construction of a canal beginning in Township 14 North, Rannge 76 West, and tapping the Big Laramie River as it issues from the mountaians.

As each alternate section has been held under the Union Pacific Railroad grant, it has been impossible to enlist capital in an enterprise through which that company would be benefited without any outlay. The railroad lands have recently been disposed of to the Wyoming Central Land and Improvement Company, and this corporation has leased this canal, and propose to enlarge it to a width of 30 or 40 feet and continue it for a number of miles beyond its present length—30 miles. Other parties have constructed ditches which are now in process of construction at an outlay of many thousands of dollars, tapping the waters of the Laramie River and Saville Creek. It is believed that many acres of land will be irrigated in the coming year, the impossibility of obtaining titles to large tracts of land having been the principal difficulty heretofore. Competent engineers are confident that much of the plains can be brought under cultivation, and although the altitude prevents the maturing of the products of the soil, except hardy vegetables, hay, and cereals, many of these will be in good demand at fair prices.

The irrigation laws are very simple, and merely vest the right to water in the prior appropriator.

I have two artesian wells, one about 1 mile south of Laramie and one about 15 miles southwest of that city, the former being 165 feet and the latter about 80 feet deep. The pipe is 4 inches in diameter, and the flow constant in all seasons of the year. I am not able to give the capacity and velocity, but they have been throwing solid streams of pure water without cessation for about thirty months. It is impossible to state what the effect will be on the climate or humidity of the atmosphere, until a number of others are sunk. This elevation is 7,000, feet on an average, above sea-level. Artesian wells can be sunk in many portions of the plains and foot-hills, and the water stored for irrigating lands not otherwise susceptible of irrigation.

Other enterprises in this Territory have offered such inducements to capital that the capabilities of irrigation have been overlooked, but now that titles can be obtained to railroad as well as Government lands, we confidently expect to show great results in the near future.

The water, climate, and resources of the Territory.

The following paragraphs from the governor's message, 1884, contains a summary of the salient and comprehensive facts regarding Wyoming:

The Territory adjoins Utah and Colorado on the northern border, Montana on its southern border, Dakota and Nebraska on their western borders, and Idaho and Utah on their eastern borders. Its area is nearly 100,000 square miles. It is one and a half times the size of New England. Its population is about 40,000, more than one-half of which is in the towns on the line of the Union Pacific Railroad with its branches, the Oregon Short Line and the Denver Pacific, the only railroad in Wyoming.

Stock raising is the chief industry, comparing with all others about as 90 per cent. to 10; capable men estimate the cultivable land of the Territory at 8,000,000 acres. As yet, however, farming is done on a limited scale, and no farm produce is shipped from the Territory.

The mean elevation of Wyoming is 6,400 feet above the sea level. The Rocky Mountains traverse the Territory from the northwest to the southeast in irregular ranges. The general face of the country is mountainous, interspersed with extensive plains. The soils range from desert lands to loams of the first quality.

The climate is remarkable. The air is pure, light, and dry. The average rain fall in Wyoming is not one-fourth that in the Mississippi River Basin; irrigation is therefore depended upon for the raising of crops. The winters are open; there are but few snow-storms, and the strong winds which form a feature of the climate usually clear away the fallen snow in a few days. The nights in summer are uniformily cool; the thermometer seldom marks above 90° in the day.

Perhaps no other portion of the United States west of the Missouri River is so well watered as this Territory, which is a portion of the continental divide, and hence a a grand water-shed, sending many streams both eastward and westward, and inclosing many minor water-sheds, which afford drainage in every other direction. Thus the central, middle, eastern, and southeastern portions are remarkably watered and drained by the North Platte and its great affluents, the Big and Little Laramie and the Sweetwater, with their numberless branches, waters, which after flowing first in a northerly, then northeasterly, then southeasterly course, finally make their way into the Missouri through Southeastern Nebraska. Northeastern Wyoming is watered by the forks of the Cheyenne, which, embracing the Black Hills, empty into the Missouri within the Territory of Dakota, and by the Powder, with its many branches flowing northeastward into the Yellowstone. The middle, northern, and northwestern portions of the Territory are traversed by the Tongue, Big Horn, Yellowstone, and Snake, which make their way through the Missouri and Columbia into the Gulf of Mexico and the Pacific, respectively. The southwestern portions are watered by the Green and Bear Rivers, the former emptying into the Gulf of California, and the latter into the Great Salt Lake, of Utah. The rivers which are at once the largest and most important, as watering very large areas, are the North Platte, Powder, Green, and Big Horn.

Of artesian wells the message says:

The great success which has attended the sinking of artesian wells in Denver and a few points in Wyoming has led to the hope that artesian water may be found at many other points in the Rocky Mountain region. A well was sunk a few years ago at Fort D. A. Russell, 3 miles from Cheyenne, to a depth of several hundred feet, but no flow of water was secured. The Union Pacific Railroad Company sunk a well last year at Green River, but failed to strike a subterranean basin of water. But these failures have not had the effect of preventing other efforts with the same object in view. An artesian well is now being sunk at a ranch 9 miles from Cheyenne, the intention of the owners being to bore into the earth at least, 500 feet in search of a flowing well. There is a flowing well at Rawlins, and at Laramie City there are two.

The unequal elevation of the various parks and plateaus of Wyoming gives rise to the belief that underground basins of water exist beneath those having an altitude less than others in the same region, and that wherever the basins find their origin there is exerted sufficient hydrostatic pressure to carry water above the surface of the lower planes.

Pure water brought to the earth's surface by artesian wells would be of great benefit in these districts of Wyoming, where the surface-water is impregnated with alkali and unfit for potable purposes. It would also render possible the raising of much additional live stock in locations where there is a scarcity of surface-water. Experiments for the purpose of ascertaining where artesian water is obtainable in Wyoming would be work appropriate to the care of the General Government, with a view to improving the value of its public lands.

The governor continues:

The one prime drawback to the development of the farming regions of Wyoming has been the lack of railroad facilities. The country through which the Union Pacific Railroad runs in Wyoming bears an appearance calculated to lead the observer to believe that, while live stock may thrive in Wyoming, the raising of crops is well nigh an impossibility. In the northern part of the Territory, however, there is a large area lying at an altitude but half as great as that through which the railroad passes, and to that region immigrants are being attracted by a soil and climate not excelled in any other section of the country. In Middle Wyoming, along the Platte River and its tributaries chiefly, large tracts of land are now being put under irrigation by companies which are managed by men whose experience leads them to believe that large dividends await those who invest in Wyoming lands, and even in Southern Wyoming, in lands situated in the midst of that bleak prospect viewed by the overland traveler to the Pacific slope, crops have been raised, especially during the past year, which inspire the liveliest hopes of successful farming upon them in the future.

The following is a list of the irrigation companies incorporated in Wyoming up to January, 1884:

The Hulbert Creek Ditch Company.
The Upper Goose Creek Ditch and Irrigation Company.
The White and Jackson Creek Ditch Company.
The Big Piney and Prairie Dog Ditch and Tunnel Company.
The Trabing Ditch Company.
The North Piney and Prairie Dog Irrigation Canal and Tunnel Company.
The Wyoming Five-Mile Ditch Company.
The Upper East Side Goose Creek Ditch and Irrigation Company.
The Wyoming Improvement Company.
The Chugwater Ditch and Irrigation Company.
The East Side Ditch and Irrigation Company.
The Hellman Ditch and Irrigation Company.
The Wyoming Development Company.
The Rutledge and Hellman Ditch Company.
The North Platte Irrigation and Ditch Company.
The Goshen Hole Ditch Company.
The McKuen Ditch and Reservoir Company.

The tracts of land which these companies intend watering, or are already watering in some cases, lie mostly in Laramie and Johnson Counties. The streams from which they take their water are Horse Creek, Chugwater Creek, Laramie River and Platte Piver, in Laramie County, and Goose Creek, Prarie Dog Creek. Clear Creek, and other smaller creeks in Johnson County.

UTAH.

Most of the facts accessible to the Department in relation to irrigation in the Great Salt Lake Basin have been given in another part of this report. The following table, from a report of the department of public works and irrigation, prepared in 1875 and published in the Legislative Journal in 1876, contains statistics which, notwithstanding that they refer to a somewhat remote period, are of sufficient value to be presented in this connection:

Statistics of public works and irrigation, 1875.

Counties.	Trunk irrigating canals.		Distributing canals.		Total cost of irrigation canals, including cost of repairs for 1875.	Annual cost of repairs.	Assessed value of property.	Rate per cent. of county tax.
	Length.	Cost.	Length.	Cost.				
Morgan	32	$3,200 00	75	$2,250 00	$8,450 00	$3,000 00	$435,032 00	.75
Summit	80	25,280 00	30	8,275 00	34,556 00	1,001 00	833,796 00	.75
Millard	60	200,000 00	600	28,800 00	229,800 00	1,000 00	415,400 00	.50
Sanpete	15	14,300 00	86	28,520 00	57,120 00	14,300 00	606,820 00	.50
Utah	80	50,000 00	500	10,000 00	65,000 00	5,000 00	2,152,800 00	.50
Box Elder	37	55,500 00	......	....	57,600 00	2,100 00	1,783,600 00	.75
Sevier	54	33,560 00	75	12,000 00	55,560 00	10,000 00	202,132 00	.75
Iron	200	32,000 00	1,600	16,000 00	48,000 00	....	428,896 00	.75
Pi Ute	5	150 00	10	300 00	450 00	....	70,000 00	.75
Beaver	146	150,220 00	......	....	150,220 00	....	293,484 00	.75
Wasatch	25	9,500 00	66	8,500 00	18,700 00	700 00	171,495 00	.75
Juab	160	17,500 00	330	2,500 00	20,000 00	....	450,000 00	.75
Davis	20	4,000 00	30	2,000 00	8,000 00	2,000 00	755,212 00	.25
Tooele	35	9,000 00	67	6,700 00	15,700 00	....	1,023,152 00	.75
Weber	142¾	251,657 05	......	....	268,540 05	16,883 00	1,915,980 00	.75
Cache	61	386,700 00	610	194,000 00	592,700 00	12,000 00	1,092,000 00	.75
Rich	10	1,000 00	110	1,500 00	2,500 00	....	132,220 00	.75
Salt Lake	108½	560,867 79	363¾	94,555 00	683,422 79	28,000 00	7,258,856 00	.75
Kane	44	42,240 00	186	79.520 00	128,460 00	6,700 00	318,692 00	.75
Washington	60	71,500 00	150	7,900 00	82,900 00	3,500 00	587,380 00	.75
Total	2,095¾	1,918,174 84	4,888¾	503,320 00	2,527,678 84	106,184 00	20,986,947 00	....

Counties.	Acres requiring no irrigation.	Acres requiring from 1 to 2.	Acres requiring from 3 to 4.	Acres requiring from 4 to 10.	Acres reclaimed from salt and alkali lands.	Acres received from swamp lands.	Length of Territorial road.	Length of county road.	Bridges costing $1,000 and upwards.	Miles of telegraph line.	Miles of railroad.
Morgan	413	1,192	2,080	333	....	....	......	47	......	30	30
Summit	8,178	505	2,017	504	....	....	......	175	......	39	39
Millard	10,132	3,330	3,332	537	....	....	70	300	1	35	......
Sanpete	5,998	3,530	5,885	1,765	....	....	......	118	......	60	......
Utah	13,420	1,997	7,968	1,997	....	....	50	150	4	47	147
Box Elder	3,540	2,211	4,422	2,211	....	....	35	42	......	181	81
Sevier	755	2,270	1,716	574	....	....	125	....	......	42	......
Iron	900	1,272	4,180	228	....	....	......	168	......	34	......
Pi Ute	3,500	201	201	....	....	....	......	40	......	......	......
Beaver	500	1,482	2,057	495	....	....	55	116	2	35	......
Wasatch	1,200	750	1,650	409	....	....	......	70	......	......	......
Juab	4,000	762	3,042	759	....	300	50	98	1	40	20
Davis	1,557	4,165	4,831	436	....	....	......	40	......	28	28
Tooele	2,069	960	1,920	959	....	....	......	134	......	80	7
Weber	5,183	1,647	9,885	1,649	....	....	43	83	2	40	37
Cache	7,547	6,467	12,935	5,405	....	....	41	131	2	36	36
Rich	2,400	265	1,593	266	....	....	......	60	......	......	......
Salt Lake	6,029	2,551	15,306	2,552	3,240	3,190	50	225	5	85½	75½
Kane	50	59	351	59	....	....	......	202	......	100	......
Washington	154	....	2,293	692	2,917	....	25	165	1	40	......
Total	77,525	35,706	87,774	21,761	6,157	3,490	544	2,364	18	961½	500½

TIME DISTRIBUTION.

In the general plan of irrigation now adopted in Utah there has been no attempt made to establish a definite "duty of water." One cubic foot per second is considered sufficient to serve 80 acres. But it is conceded on all hands that the amount of land served by the same ditches is very much larger in area than formerly. The cause of this cannot be an increased rainfall, for the records show, if anything, a very slight decrease. Here, as elsewhere in the arid region, immigration and irrigation have preceded modifications of atmospheric phenomena, as shown, for example, in the presence of dew where it was unknown before. This, however, is so slight as not to account for the extension in area of the "duty of water."

The reason will be found, doubtless, in the increase of terrene humidity. The saturation of the subsoils by the constant "seepage" of the water laid on the surface with the capillary power of plant life in drawing to the surface the subterrene waters with which the arid intra-mountain region seems to be so largely endowed are the main causes of the larger economy of water duty. Of course this is aided by a more careful and intelligent use of the water. The time system in vogue in Utah has helped to increase this skill. Colonel Nettleton, State engineer of Colorado, says:

> It is well worth our while to carefully notice two very remarkable results which have been developed by the Utah method of dealing out water; these are, first, securing the greatest duty of a ditch, and, second, the development of quite a high duty of the water carried by the ditch. The first is secured by the hour rotation or time method, which requires the users to take the water belonging to them at such days and hours as are designated by the water-master, be it night or day. By the enforcement of this requirement, it is estimated that the effectual capacity of a ditch or canal is fully doubled over what it would be by the all-at-one-time using system. (Colorado State Report for 1883-'84, page 76.)

This horary or time system is the plan long in use in Northern Italy. The following form of a distribution table will illustrate how it works in Utah:

Hourly distribution table for the year —— of the water of the —— ditch, carrying —— cubic feet per second, of which the period of rotation is eight natural days or one hundred and ninety-two hours:

No.	Name of irrigators.	Number of hours for each.	Commencement of horary distribution.		Termination of horary distribution.	
			Hour.	Day.	Hour.	Day.
1	A	14	4 a. m	April 1	6 p. m	April 1.
2	B	16	6 p. m	April 1	10 a. m	April 2.
3	C	24	10 a. m	April 2	10 a. m	April 3.
4	D	18	10 a. m	April 3	4 a. m	April 4.
5	E	2	4 a. m	April 4	6 a. m	April 4.
6	F	25	6 a. m	April 4	7 a. m	April 5.
7	G	30	7 a. m	April 5	1 p. m	April 6.
8	H	23	1 p. m	April 6	12 m	April 7.
9	I	19	12 m	April 7	7 a. m	April 8.
10	K	21	7 a. m	April 8	4 a. m	April 9.
	Total	192				

NOTE.—The rotation again commences in the same order with A.

NEW MEXICO.

Under date of January 22, 1886, Governor Ross, of New Mexico, wrote that—

> We have no established system of irrigation. The natives of the Territory farm entirely by irrigation, but they have no organized companies, the work being done in primitive ways by neighborhood and individual effort, making it impossible to procure any official or reliable data. A few American companies have been organized in the past year or two, of which I am able to give you the following addresses:
>
> Ira E. Leonard, Socorro; General R. E. Carr, Santa Fé; Hon. F. A. Manzanares, Las Vegas; Greylands Ditch Company, Lookout, Lincoln County; McDermott Irrigating Ditch Company, La Plata Valley, Rio Arriba County; Rio Grande Irrigating and Ditch Company (care W. R. Childers), Albuquerque; Albuquerque Irrigating and Ditch Improvement Company (care R. H. Greenleaf), Albuquerque.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.*

E. Gillett, Socorro, writes:

Socorro County is between longitude 106° and 111°; latitude, between 30° and 35°. The altitude is 4,600 feet. I confine my report to a tract of 20 miles in length, within the Rio Grande Valley. It is 5 miles in width, which is about the width of the valley. Average size of ranches, 20 acres.

P. A. Simpson, Socorro, writes:

The location is central New Mexico. The post-office is Socorro, Socorro County. It was settled in 1549, afterwards abandoned, destroyed by Indians, and recolonized in 1816. Farms vary in size from 1 to 100,000 acres. Average size of ranches, 20 acres.

Alex. Gusdorf, Taos Valley, writes:

The Ranchos de Taos is located in Taos Valley, Taos County. There is also Las Cordovas and Ranchito. These have a population, respectively, of 1,300, 400, and 800, having under cultivation somewhere in the neighborhood of 5,000, 2,000, and 4,000 acres, respectively; all are under ditch and subject to irrigation.

(2) *Original value of land per acre; present selling price; state if the purchase of land carries water also; if not, rent or price of latter per acre.*

Alex. Gusdorf writes from Taos Valley:

The value of land under cultivation ranges from $10 to $30 per acre, according to quality and locations; ditches are mostly owned by the community. The land has been cultivated nearly two hundred years.

P. A. Simpson, Socorro, writes:

Land is worth from 50 cents to $200 per acre. Water for irrigating ditches can be obtained by all land owners by working the same once a year.

E. Gillett, Socorro, writes:

The value of land carrying water is about $50 per acre. Rent for water is $5 per acre.

(3) *Products of land, amount, market and average value of crops; how long planted. Are fruits grown?*

E. Gillett, of Socorro, writes:

Corn yields 25 bushels; wheat, 20 bushels; oats, 30 bushels; barley, 20 bushels; and peas, 55 bushels per acre. The average value is 1 and 1¼ cents per pound. Length of time planted, five months. Cabbage, beets, tomatoes, turnips, melons, sweet potatoes are also grown. Also fruits of all kinds.

P. A. Simpson, of Socorro, writes:

Our products are corn, wheat, oats, barley, cotton, hemp, flax, tobacco, and hops. All the vegetables and fruits of the temperate and semi-tropical zones thrive and yield profusely.

Alex. Gusdorf writes from Taos Valley:

Wheat, corn, oats, peas, and all kinds of vegetables are grown. Wheat will average 20 bushels, corn 25, and oats 30 per acre, the value being 75 cents for wheat and corn, and 60 cents for oats per bushel. The lands have been farmed for nearly two hundred years. Formerly it was thought fruits could not be raised, but I find apples, pears, plums, cherries, and all kinds of small fruits are doing well, and a great many trees have been planted in the last ten years.

(4) *Extent of irrigation works and their character; source of supply, method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

Alex. Gusdorf, Toas Valley, writes:

All land under cultivation has to be irrigated, and all the farming settlements have community ditches, with a never-failing supply of water from the Rio Grande de Taos, the Pueblo, Rio Chequito, and Taos Creek. There is a great deal of land which could be brought under cultivation by putting up reservoirs along the river banks. Irrigation costs about $2 per acre during the season.

P. A. Simpson writes from Socorro.

Irrigation works consist of common ditches only. They convey the water to and on the cultivated lands bordering on the Rio Grande and other streams. The plains are used for grazing stock, and the mountains yield, besides minerals, abundant and nutritious grasses to goats and sheep.

E. Gillett, Socorro, writes:

The extent of irrigating ditches is 50 miles. Their average width is 10 feet; depth, 4 feet. The supply is the Rio Grande. In distributing you take as much as you need. Ditches cost $10,000; present value, $25,000; area available, 5,000 acres; prospectively, 15,000 acres.

(5) *Climatic conditions, temperature, and rainfall; results of observations, if any, as to the influence of irrigation on moisture of the earth or sky; effects of irrigation on health, fertility, &c.*

P. A. Simpson, Socorro, writes:

The climate is mild and equable; snow and rainfall light. Seasons are divided into dry and rainy; the latter lasts about six weeks.

Alex. Gusdorf, Taos Valley, writes:

Our climate is splendid; the lowest temperature ever seen here, and that this winter, was 4° below zero, and the highest ever known was 96° in the shade. Rainfall has changed some in later years. Formerly we had no rains in spring and not until August. The last few seasons we have had considerable rain during May and June.

E. Gillett writes from Socorro:

Mild temperature, ranging from zero to 90° above. Rain falls about four times in twelve months. I don't know of any influence irrigation has on moisture of the earth and sky or on health. Muddy water is considered good for light or sandy soil as a fertilizer.

B. Rosenfeld, Georgetown, Grant County, makes the following reply:

There are 30,000 acres of irrigated land in this county. This county comprises 18,000 square miles, of which area fully one-fourth could, with proper water facilities, be made productive. As it is, regular farming is carried on only along the Mimbres and Gila Rivers, The extent of canals and laterals is about 300 miles, These ditches are mostly community-owned; there are some private ditches. There are one, two, and even more ditches in every township, and where practicable, that many on each side of the stream. I could not get any data about cost, as everybody living along the course of a ditch and using water from it, even if only for household purposes, is required to perform his pro rata labor on the ditch, as regulated by local custom. Wells are mostly used for stock. One artesian, the first, is now being bored at Deming. Land under irrigation is not flooded in one body, but shortly after planting it is laid off in parcels in order to take advantage of the irregularities of the soil. Thus each parcel has to be bordered, and, when irrigated, has to be flooded in its turn. This is necessarily a very slow and tedious process, and makes it almost impossible to determine the quantitative duty of water. This peculiarity of our system makes farming so costly here as to exclude every thought of competing with Kansas, and our farmers are satisfied when their grain crop pays their store bills, trusting to poultry, hogs, and gardening for their profits.

DAKOTA.

H. M. Gregg, of Spearfish, writes:

Upon the discovery of gold mines in the Black Hills in 1875 the valleys lying at the base of the Hills were settled by farmers from the Western States and Territories. The lands were located in conformity with the land laws of the United States.

The farms average about 320 acres, about one-half of each in the valleys being good agricultural land. These valleys are watered by streams rising in the Black Hills, the water of which is pure and cold. The present selling price of improved farms, is about $10 per acre in the valleys where irrigation can be used. Desirable farms of 160 acres, lying in the Spearfish Valley, have been sold for $20 per acre.

All the small grains of the Northern States grow well here, notably wheat and oats.

The nights being cool at all seasons of the year, corn cannot be said to be a good crop, although a good crop is made in favorable seasons.

The mines in the Hills are our market, and prices are good. 50 bushels of oats to the acre is a fair yield.

Wheat will average 22 bushels, although 36 bushels are grown on many farms. All the hardy vegetables, such as potatoes, cabbage, turnips, beans, peas, melons, squashes, cucumbers, and tomatoes, grow in great quantity and of superior quality.

Fruit raising is yet in an experimental state. Much trouble has been experienced with Eastern-grown trees. This we hope to overcome when trees are grown from the seed here. Tame currants, raspberries, gooseberries, strawberries, &c., thrive and bear fruit in great profusion.

The irrigating ditches are owned by the farmers who own the land; sometimes four or five who own adjoining farms club together and construct ditches carrying 1,000 or 2,000 inches of water, the source of supply being the streams running through the valleys, which have a fall of about 50 feet to the mile.

Ditches are connected with the stream and have a regular grade of about one-third inch to the rod, which admits of their soon reaching the higher points in the valley. From the ditches the water is distributed over the cultivated fields by furrows run in such a manner that the water will run slowly, and not cut or wash away the loose soil. With 100 miner's inches of water (1,250 gallons per minute) and the labor of one man to attend to distributing the same, 10 acres per day can be thoroughly irrigated. In ordinary seasons a crop of small grain should be irrigated twice.

Owing to the altitude, the dryness of the atmosphere, and the purity of the water, no danger to the health of residents in the irrigated districts need be apprehended.

As a fertilizer nothing can compare with water. All things being equal, irrigated and will produce double the amount that unirrigated land can be made to produce.

D. T. Harrison, Minnesela, Butte County, Dakota, writes:

Minnesela is the county seat of Butte County; it is located on the Red Water, out of which water is taken in many ditches for 20 miles above, and 10 below Minnesela, covering many thousands of acres of land, mostly owned by farmers in 160 to 480 acre tracts.

Many improved farms are now held at from $20 to $30 per acre.

They will produce all kinds of grain and vegetables that grow in any of the Northern States. As they have been only four or five years in cultivation, fruits are not grown extensively. Wheat yields 20 to 35 bushels per acre, at $1 per bushel; oats 30 to 80 bushels per acre, at 75 cents per bushel; potatoes 100 to 300 bushels per acre, at 60 cents per bushel.

Ditches are taken out of Red Water and its tributaries, costing from $500 to $5,000 each. They are owned by private parties and corporations.

The stream runs many thousand inches more than is used. The climate is very dry.

Irrigation has no perceptible effect on the moisture of earth or sky, and none on health. It increases the fertility of the soil very much, and is equal to a good coating of manure, outside of the benefit derived from the use of water.

ARIZONA.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.*

William A. Hemrick writes from Phœnix, Maricopa County:

Phœnix is situated on the north side of Salt River, about 14 miles north of east from the junction. We have no colony, in the common acceptation of the term. We have a very prosperous county. The area of the agricultural part of the valley is 10 by 40 miles. The first settlement here was in 1867, and we now have 10,000 people.

I. Brooks, Florence, Pinal County, writes:

I am located in Pinal County, which is about the center of the Territory. Farms range from 40 acres to 640 acres. The land is prairie, farmed mostly by inexperienced hands. Well farmed it will yield everything in abundance (Irish potatoes and apples excepted).

E. D. Tuttle, Safford, Graham County, writes:

My location is in that portion of the Gila Valley known as the "Pueblo Viejo," or "Old Villages." It is in Southeastern Arizona, Graham County. Post-offices: Solomonville, Safford, Pima, and Fort Thomas. Length of valley from the cañon at the western or lower end, where the Gila River cuts through the Pinal or Graham range of mountains, just below the San Carlos Indian Agency, to its eastern or upper end at the narrows, where the river cuts through the Gila range of mountains, is about 75 miles; the average width of the arable land is 2 miles, making about 150 square miles of arable land, not including small patches on the lateral streams. The size of farms is generally 160 acres, according to Government subdivisions.

(2) *Original value of land per acre; present selling price; state if the purchase of land carries water also; if not, rent or price of latter per acre.*

William A. Hemrick writes:

The Governmental price of land was $2.50 per acre; present selling price, from $10 to $100 per acre, with water for irrigation. The cost of water per acre per annum varies in the different lands—seventy-five cents to $1.25 per acre.

E. D. Tuttle answers:

The present settlers mostly have their titles by entries made under the pre-emption, homestead, and desert-land laws. The price fixed by Government within railroad grant limits is $2.50 per acre.

The settlers have constructed their own canals for irrigating. When lands are sold a right to vote goes with the land, otherwise the land would not sell for anything. No water is rented, as the land owners own their own water. Land with water rights is $5 to $10 per acre.

I. Brooks writes:

Improved farms with water to irrigate, $25 to $40 per acre. Some farmers have to rent water and it costs $1.50 per acre.

(3) *Products of land; amount, market, and average value of crops! How long planted? Are fruits grown?*

E. D. Tuttle writes:

This being a semi-tropical climate the range of production is very great. Everything that will grow in any part of the United States, North or South, will grow here, with proper cultivation and attention. Corn, wheat, barley, oats, beans, sorghum, and potatoes, both sweet and Irish, are the principal crops now grown. Corn and barley are mostly consumed by the Government posts. Prices: Corn, $1.50 per cental; barley, $1.75 per cental; wheat, $1.50 per cental. Valley first settled in 1874, surveyed in 1875 and 1885. Fruits are grown in some of the colder orchards, most of the orchards are too young to bear. Late frosts cut off peaches and apricots occasionally. Quality of fruit good.

William A. Hemrick writes:

Wheat averages 1,000 pounds; barley 1,200 pounds per acre; average price for the past three years about $1.10 per cental for barley, and $1.25 for wheat. Alfalfa yields 7 tons per acre; price, $5 in stack. All kinds of fruit are grown here and produce abundantly. This valley, Pueblo Viego, is especially adapted to the growth of alfalfa, or lucerne, and produces five crops of hay a year. Probably by irrigation all the tame grasses and clovers would thrive. They have not been yet tested.

(4.) *Extent of irrigation works and their character; source of supply, method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

E. D. Tuttle writes:

The canals that have their source in the Gila River, commencing at the head of the valley, are as follows:

Name.	Length.	Width.	Value.
	Miles.	*Feet.*	
San José Canal	6	8	$7,500
Montezuma Canal	7	12	15,000
Darby Canal	5	*5	3,000
Mill Canal	15	18	20,000
Sunflower Canal	2	6	3,000
Central Canal	9	8	10,000
Oregon Canal	4	7	4,500
Smithville Canal	5	8	5,000
Nevada Canal	4	7	4,500

* Not complete.

Seven other canals averaging about 6 feet wide, total length 35 miles, $20,000. The above are approximate as to size, length, and value.

(5) *Climatic conditions, temperature and rainfall, results of observations, if any, as to the influence of irrigation on moisture of the earth or sky, effects of irrigation on health, fertility of soil, &c.*

Mr. E. D. Tuttle writes:

Generally dry in winter, the thermometer seldom drops to freezing; average temperature day and night is 55° or 60°. In summer, the hot weather commences about the middle of May. Thermometer never goes above 110°; average summer temperature, 75° to 90°. Owing to the dryness of the air the heat is not depressing nor sultry. Nights are cool. We have two rainy seasons, July to September, and again, though less in quantity, in December. The average amount of rainfall in year is from 8 to 14 inches. Rains are sufficient to produce the grasses native to the country, but insufficient for agriculture. They help mature crops with irrigation. Irrigation increases the atmospheric moisture, and probably the rainfall.

Malarial fevers or chills prevail in the bottoms. The uplands are free from malaria and remarkably healthy. No other diseases are prevalent. The climate is very favorable for all lung diseases.

Cultivation decreases the tendency to chills or ague and fever; I don't see that irrigation increases them.

Irrigation promotes the fertility of the soil, as at times the water of the river is heavily charged with sedimentary matter from the mountains, which is left upon the soil. Irrigation produces a heavy growth of nitrogeneous plants, which, when turned under, add the element in which these dry soils are deficient; it also benefits those soils which are too heavily charged with mineral salts by washing them out and down into the subsoil.

Lands in the Gila Valley, which the Indians have cultivated in wheat two hundred years, show no sign of failing. We have no cyclones, nor very high winds; but cool breezes are constant during summer.

There is no wind during the season of rain, of which there is just enough to moisten the earth and prevent dust.

William A. Hemrick writes:

Irrigation does not seem to affect the health of the people. The country has always been extremely healthy and is so now.

I am of opinion that irrigation assists in keeping up the land. Successive crops do not materially weaken the soil.

Clark Churchill, of Phœnix, gives an interesting account of irrigation in the Salt River Valley, as follows:

The Arizona Canal Company is a corporation (domestic), and has completed its canal from near Fort McDowell, on Salt River, to Cain Creek, in Maricopa County, Arizona Territory.

The cost was estimated at from $500,000 to $550,000. The present estimated value is $1,000,000. The water is taken from Salt River, about three-fourths of a mile below the Rio Verde, by means of a dam, and thrown into the main canal, which is 36 feet wide on bottom and 59 feet on top, 7 feet deep, and 41 miles long.

The source of water supply is only the natural flow in Salt River. There is no reservoir to store water. The variations in supply are very great. In most years water is low in June and July and October. The supply might be regulated by reservoirs, which can be built in the mountains up the stream, so as to furnish a regular quantity in the dry months. The area which this canal will supply is about 100,000 acres, which will increase as the land becomes filled with water by constant irrigation.

The area susceptible of being irrigated, if sufficient water could be had, is 250,000 acres. This additional water could be furnished by storing it in winter.

The unit heretofore in use is 1 cubic foot per second. The rate has been by the season, which includes nearly the whole year here.

Service, which is by flooding, is continuous, except during period necessary to repair canal. Distributing regulations are made by the company. There are no general laws on the subject. Before irrigation the land is useless desert. With irrigation it is intrinsically worth $100 per acre.

I have not observed any change in precipitation. The earth when irrigated has filled with water, so that wells which were formerly 60 feet deep to get a supply, are now filled with water to within 10 or 12 feet of the surface.

E. D. Tuttle says:

In order to make the unoccupied land valuable, it is essential that ditches should be made larger than those used now, so that the water may be obtained from higher portions of the valley.

If Government would encourage sinking artesian wells by gift of lands reclaimed, the area of tillable lands would be largely increased. The great San Simon Valley, which is a branch of this valley, and extends to the Mexican line, is level and fertile, but is devoid of running water. With the Chihuahua Range, including Graham Range on the west, at an elevation of 6,000 to 10,000 feet, with snow two-thirds of the year, there is an inexhaustible water supply in the valley.

Pine timber is abundant but difficult of access.

I. Brooks says:

Our best crops are Egyptian corn and alfalfa hay; wheat and barley do well; it is a great grape country, and I think cotton would do well.

O. F. Thornton, Gila Bend, writes:

Location, south side of the Gila River, at Oatman Valley, 15 miles from Painted Rock Station, on the Southern Pacific Railroad; post-office, Gila Bend, Maricopa County. The land covered by canal aggregates 10,000 acres. The canal is to carry 40 cubic feet of water per second. Name of place Dendora, meaning *golden trees*. Canal is 6 feet on bottom, with slope of 1 foot to 1 of bank, carrying 3 feet in depth and giving sectional area of 27 feet. The grade of the canal is 19 inches per mile, which gives a mean velocity of 2 miles per hour. Source of supply is the Gila River. Service per acre one-fourth of 1 inch; three irrigations per year for grain crop, and for alfalfa one irrigation each cutting. Lowest winter temperature 24°. Long, warm summers. Light rainfall. Irrigation produces no appreciable effect upon atmospheric precipitation. Not deleterious to health. Stimulates the fertility of the soil. With copious winter irrigation, orchards, after first year, will require no summer irrigation.

Large irrigation works are in process of construction along the Gila.

The Southern Pacific Road runs parallel with the valley, 175 miles east from Yuma. A population of 25,000 can easily be supported in this valley. Sorghum grows luxuriantly. The osage will flourish finely; all fruits also.

The Florence Canal and Land Company, Pinal County, have nearly completed an irrigating canal, running from the Gila River at the point where it leaves the mountains, southwest onto a level tract of land, 500 miles in extent, lying directly south of Florence and extending to the Southern Pacific Railroad. The canal will cost several hundred thousand dollars and will tap the Gila at a point where a never-ending flow will be secured, sufficient abundantly to water the entire tract. For irrigation it is one of the best-located pieces of land in the Territory, and it must have been reclaimed in this manner centuries ago, as there are still in existence the remains of canals used by the aboriginal inhabitants of the country.

TEXAS.

James B. Newcomb, of San Antonio, writes:

There are 50,000 acres of irrigated lands in Bexar County, valued at from $50 to $300 per acre. All irrigation works in the limits of San Antonio are vested in the city corporation; those outside in individual land owners. Water is used by the hour, each land owner paying for so many hours of water. The price is nominal.

The system of irrigating canals now in use in our city and in the valley below was constructed under Spanish rule over one hundred years ago. It is estimated that there are about 50 miles of these canals. Irrigation is used chiefly for gardens. No use is made of irrigation for farming purposes in this county. The rainfall is generally sufficient to make all kinds of grain crops, and cotton never fails. Within the past few years large areas formerly given up to stock raising have been converted into thrifty farms. Many of the old irrigating canals have fallen into disuse. This is an agricultural county without the use of artificial irrigation.

Oats and rye never fail. Wheat is becoming a standard crop. All kinds of fruit are being successfully planted.

Mr. H. C. Smith, of Mount Blanco, Crosby County, Texas, writes the Department as follows:

I herewith submit to you my practical experience for the seven years that I have resided here—that is, in the region of the Staked Plains, which comprises the counties of Crosby, Lubbock, Hale, Floyd, Brisco, Swisher, and part of Dickens.

(1) Water can be got by digging or boring at a depth of 10 to 100 feet in any of above counties. The farther northwest of here the more shallow the wells. The water is mostly freestone water. Some of the water is found in a deep bed of quicksand and some in a shelly rock. The water rises usually from 2 to 4 feet when struck, and the supply is inexhaustible for windmill or other pumps.

(2) The above counties are in from a rolling prairie, interrupted by the streams of the Brazos River, North and South Double Mountain Forks, White River (or the French Water Fork of the Brazos), and the numerous branches running into it and Tule Cañon and its branches. These all run in a southeast course, with sufficient water and water-power to drive all machinery necessary to reduce the products of this section, if it were fully populated.

(3) The Staked Plains are covered with numerous basins or lakes, some of which have water the year round. The water of these basins is supplied by rains, and they generally hold water nine months in the year.

(4) The soil of these counties cannot be surpassed in any country. For productiveness it is equal to the prairies of Illinois, and it is covered with a heavy sod of th best grasses known.

I sunk one well in Blanco Cañon, at my place, 60 feet deep and the water rose 32 feet. It is my opinion if the water were confined it would rise to the top. Artesian water can be got here, I am certain, at not over 500 feet deep.

There are many boiling springs of great force—not hot water, but water acting as boiling water forced up from below the surface-water.

The country is denuded of timber; oats, barley, rye, beans, sorghum, durrac corn, sweet and Irish potatoes, pumpkins, and in fact everything that grows anywhere else, will grow here, except Indian corn, which the worms destroy.

Every year the valleys of all streams and small creeks are full of wild fruits, such as five kinds of plums, three kinds of grapes, mulberries, currants, elderberries, also walnut, pecan, and other nuts.

I have now an orchard of domestic fruits, including peach, plum, currant, mulberry, and apricot trees, and gooseberry and raspberry bushes; also vigo grapes and a great many forest trees. All are doing well.

Rain has increased very notably ever since I moved to this place. The proof of the same is the showing of our crops. Where the country is not overstocked with cattle and sheep the grasses seem to take a stronger hold in the ground. I have the alfalfa and the Johnson grass growing here in perfection.

Mr. Morgan Jones, president of the Fort Worth and Denver City Railway Company, writes under date, Fort Worth, Tex., September 11, 1885, as follows:

In reply to yours asking for information as to water supply, &c., I would submit the following observations, derived from the locality of our road. Our line commences at Fort Worth, Tex., and runs in a northwesterly direction to Wichita Falls, a distance of 114 miles. Starting at this point, Fort Worth, we find an abundance of reliable water, both from the Trinity River and from wells, the latter at a depth of an average of 280 feet; after leaving this point, and throughout the extent of our line, the supply of water for locomotive use from wells is quite precarious. At several points we have bored wells to a depth of 300 feet, and so far we have found but one or two that yielded any considerable supply of water. These wells would furnish an abundant supply for family use, but no deep wells have been bored for the purpose of reaching artesian water. With these difficulties, our experience has led us to adopt and rely upon the use of artificial supplies of water. The average rainfall along the line is about 24 inches per annum. It is probable four-fifths of this supply falls during the winter and spring months, the remaining mon ths very seldom giving a rain of sufficient amount to flow on the surface. The result is, we have a few months that give us high waters in the streams, and give a large flow of water in the depressions and ravines over the surface of the country

By selecting the proper places for reservoirs we can, at small expense, locate a dam that will hold the water that flows into a ravine during the wet season, and this furnishes an abundant supply for the whole year. This method of water supply is now adopted by many stockmen, and experience shows it is a cheap and reliable source of water supply for the country at large.

These reservoirs, when constructed so that the retained water shall obtain a considerable depth, remains pure and of moderate coolness through the hot season, giving water suitable for drinking and domestic purposes.

It is affirmed by the old settlers that the rainfall is materially on the increase, and I would say that my own observations confirm this opinion. If this increase goes on, we may expect in a few years to have more reliable supplies of water from subterranean sources, and a resort to wells for such supplies may become practicable.

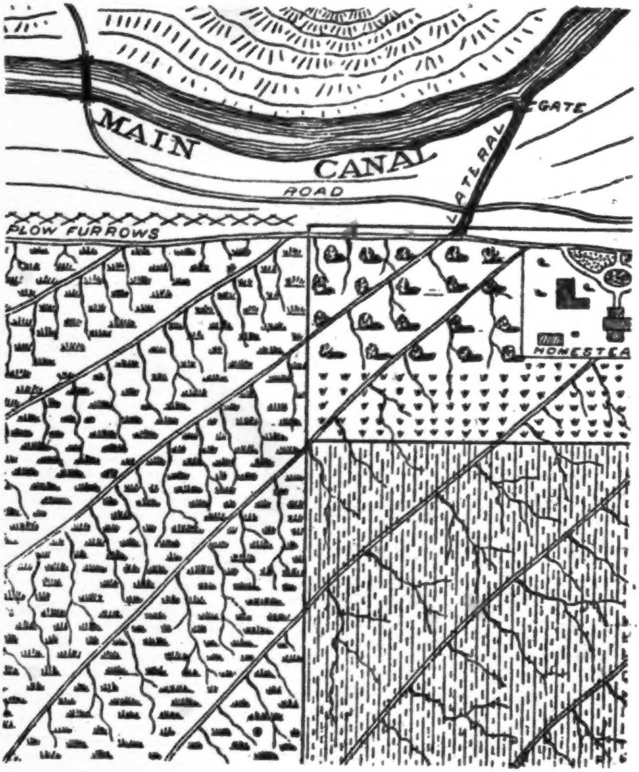
Mr. J. E. Wallace, of the Texas Pacific Railroad, sends the following tabular statement, showing wells on the Rio Grande Division thereof:

West of Fort Worth.	Location.	Depth.	Description.	Supply in twenty-four hours.	Character of water.
Miles.		*Feet.*			
0	Forth Worth	280	Well 7 inches in diameter (abandoned).	Limited	Good.
30.6	Weatherford	343	Well dug 43 feet, bored 300 feet; 6½-inch hole.	None	
98.6	Colony Fork	266	Well dug 51 feet; bored 215 feet; 7-inch hole.	do	
117.3	Sandy Creek	222	Well dug 42 feet; bored 150 feet; 7-inch hole (abandoned).	10,000 gallons.	Fair.
130.2	Baird	400	Well bored 400 feet; 7-inch hole	None	
146.7	Clyde	238	Well dug 42 feet; bored 196 feet; 8-inch hole		
160.2	Abilene	640	Well dug 40 feet; bored 600 feet; 7-inch hole (abandoned).	None	
228.7	Colorado	106	Well bored; 8-inch hole	20,000 gallons	Good.
237.9	Westbrook	90	Well bored (abandoned)	Abundant	Alkaline.
249.0	Tatan	210	do	do	Do.
258.9	Signal Mountain	265	do	do	Do.
298.1	Lagonda	46	Well bored; 8-inch hole	do	Good.
327.5	Odessa	53½	Test hole; 7-inch diameter	do	Do.

West of Fort Worth.	Location.	Depth.	Description.	Supply in twenty-four hours.	Character of water.
Miles.		*Feet.*			
368.8	Aroya	136	Well bored; 8-inch diameter	Abundant	Good.
347.4	Metz	320	Well bored; 8-inch diameter (abandoned)	....do	Alkaline.
357.7	Sand Mills	80	Well bored; 8-inch diameter	....do	Good.
419.0	Toyah	256	Two wells, each 8-inch diameter and bored 256 feet deep.	40,000 gallons	Alkaline.
419.0	....do	836	One well bored; 10-inch diameter	400,000 gallons.	Do.
443.5	San Martine	236	Well dug 36 feet; bored 200 feet; 8-inch diameter (abandoned).	Limited	Do.
451.6	Antelope	51 62	Two wells bored; 8-inch diameter (abandoned.	None	
462.0	Batacho	325	Well bored; 8-inch diameter (abandoned)	....do	
462.0	....do	227	Well bored; 10-inch diameter (abandoned).	....do	
470.0	Wild Horse	343	Two wells bored; each 8-inch diameter and 343 feet deep.	40,000 gallons.	
488.4	Van Horn	590	Well bored; 10-inch diameter	....do	Good.
488.4	... do	571	Well bored; 8-inch diameter		
491.3	Carrizo	250	Well bored; 8-inch diameter (abandoned).	800 gallons	Do.
491.3	....do	300	......do	None	
507.5	Eagle Flat		Now drilling at this point, as yet no result.		
521.5	Sierra Blanco	1,160			
521.5	....do	25 26	Well bored; 10-inch diameter Two wells; 8-inch diameter (abandoned).	None Limited	Fair.

COLORADO.

Numerous streams, having their fountain-heads far up in the mountains, flow eastward into the valleys. Beginning up in the mountains on some of these streams, so as to get elevations of several hundred feet above the valleys, irrigation canals have been constructed and carried out along the uplands 50 to 100 miles. From these main canals ditches, usually called laterals, are constructed, so as to carry water to the farms along the slopes and down in the valleys. The water is brought in the lateral to the highest part of the farm, and if the crop be in drills, such as potatoes or corn, it is allowed to run between the drills. If the field be in wheat or oats or other such crop, trenches of 12 to 18 inches wide, made with the plow or shovel, are run from the highest part to the lowest, at distances of 50 to 100 feet apart. If the slope of the field be not too great these trenches are usually made in direct lines, but if the slope be such as to cause the water to run too fast the trenches are made diagonally, so as to obtain a proper grade, or are made in a winding course, according to the contour of the ground. The water from these trenches is rapidly absorbed by the loose, cultivated soil, until almost, if not every part of the land between the trenches is made moist. Should any portion not be receiving sufficient water the man in charge of the irrigation makes a small trench to that part with his shovel. If the field be large the water is let upon only a part of it at a time, and when that part has received enough moisture the water is turned off it and is turned on another part. The water is turned off or on certain parts of the field by simply throwing a few shovelfuls of earth across the "head," or upper end of the trench, or by taking out a few shovels of earth, as the case may be. Two irrigations, equaling each time a rainfall of 3 to 5 inches, are usually sufficient for wheat, and more than three irrigations are never applied to it. The following diagram illustrates the method in use:


MAIN
CANAL
GATE
LATERAL
ROAD
PLOW FURROWS
HOMESTEA

LETTER OF THE STATE ENGINEER.

Hon. E. L. Nettleton, the State engineer of Colorado, transmits to the Commissioner of Agriculture a copy of his annual report, and writes as follows:

Regarding the ownership, control, and value of water in our State for the purpose of irrigation, I will say that, under our constitution and laws, the water of every natural stream belongs to the public and is under the control of the State. The right to divert any unappropriated water for a beneficial use can never be denied. Priority of appropriation is recognized in this way. Those using the water for domestic purposes have the preference; the next preference is given to those using it for agricultural purposes; after these comes the right to use it for manufacturing purposes. The law requires every appropriator of water from the natural streams to prove his claims as to date and amount of appropriation. When this is done, and four years have elapsed (in which to correct any errors that may occur in dates and quantity), such claims become valid and a matter of record. The State engineer and water commissioners are the officers of the law to look after the division of public waters, according to the rights of each appropriator.

This method of establishing and protecting the rights of the people to the use of the public waters seems to be as good as can be devised, and much has been done within the last five years in enacting and enforcing good laws, which have given great value and confidence to irrigation enterprises within the State.

The cubic foot per second is the unit of measure of water generally used, especially by the large irrigation companies.

When the water is sold in perpetuity by the canal proprietors to the agriculturist, the former generally agree to furnish and measure it at the canal, and receive about $750 for a cubic foot per second, which is to be furnished during the irrigation season, or from May 15 to August 15 of each year.

When the water is sold for a single irrigating season it brings from $1.25 to $2.25 per acre.

The duty of a cubic foot of water per second varies with the kind of soil and the crop irrigated, but may be assumed to be capable of irrigating 55 acres on an average. I predict that the duty of water for irrigation purposes will be increased very materially within the next ten years. This will be brought about mainly by better preparation of the land and ditches and a more skillful application of the water.

While the observations of the rain-gauge do not show any increase of moisture precipitated as rain and snow for the past fifteen years, yet there is a very perceptible increase in the humidity of the atmosphere surrounding the irrigated districts.

In these places it is now a very common thing, after a still and clear night, to find heavy dews on the vegetation in the morning, while in the unirrigated places on the plains dews are seldom seen.

I have yet to learn of any ill effect upon the health of the people in the irrigated districts of Colorado caused by irrigation.

Reversed irrigation or drainage has been practiced but little in our State, although it is needed in some places.

Water in perpetuity for an acre is more valuable than the land before the water is applied, the former being worth from $10 to $15 per acre, while the latter in its native condition is only worth from $1.25 to $5 per acre.

The amount of agricultural land in our State is limited by the amount of water available, hence the water for irrigation purposes is a key to the growth and prosperity of agricultural interests in Colorado.

Our country is comparatively new, therefore it is exceedingly difficult to collect reliable data concerning these things.

DESCRIPTION OF THE WATER DISTRICTS.

Under the admirable system adopted in this State the irrigable area is divided as follows for purposes of distribution, supervision, and the adjudication of claims and disputes:

District No. 1, *South Platte division.*—This district comprises the lands irrigated from ditches and canals taking water from the South Platte River, between its intersection with the State line of Colorado and Nebraska, and the mouth of the Cache la Poudre River. There has been filed a statement of seventeen ditches and canals. The total amount of water claimed by all ditches on record is 5,404.78 cubic feet per second. Since 1882 several large canals have been constructed. It is claimed that the flow of water in the Platte River through this district is much more uniform than formerly, which is undoubtedly true, and is due to the effect of the irrigating canals on the stream above by reducing its flow in the flood season. After high water its natural flow is increased by the return into the stream of a portion of the water which is commonly call seepage.

District No. 2, South Platte division.—This district comprises all lands that can be irrigated from the South Platte River and its tributaries (except the Big Tompson, Saint Vrain, and Clear Creek) between the mouth of the Cache la Poudre and Cherry Creek. There are thirty-five ditches and canals in this district, most of which have their rights of appropriators established by a decree of court, dated April 28, 1883. The total amount of water appropriated in this district, including the amount decreed and claimed by statements filed in the office of the county clerk, is 3,642 cubic feet per second.

District No. 3, South Platte division.—This district comprises all land irrigated from waters of the Cache la Poudre and its tributaries. Decrees were rendered in this district dated April 11, 1882, which established the priority of appropriations of fifty-three ditches and canals.

District No. 4, South Platte division.—This district includes all lands irrigated from the waters of the Big Tompson and tributaries. The rights of claimants to water in this district were established by decree of the court of May 20, 1883. There are twenty-eight ditches and canals in this district, having a total appropriation of 3,397 cubic feet per second. Difficulty was found by the commissioners in measuring the water before flumes were put in the ditches, but since then, by using the rating tables, the water is divided to the satisfaction of all concerned. Under the law, and by means of these flumes, the division of water in time of scarcity has given general satisfaction.

District No. 5, South Platte division.—This district comprises all lands irrigated from the waters of Saint Vrain Creek and its tributaries, except the Boulder, its tributaries, and Coal Creek. The rights of claimants to the use of water and the order of priority of such claims were established by decree of court. There are seventy-three ditches and canals in this district, having by decree a total appropriation of 80,486 "customary inches" or about 2,096 cubic feet per second, the "customary inch" being assumed to be equal to the statutory inch, which is .026 of a cubic feet. Measuring flumes have been put into a few of the ditches, and a partial gauging and rating of these have been made. The area cultivated under the canals is estimated to be larger in proportion to the water supply than in any other district in Northern Colorado with one exception. A great deal of contention has existed here.

District No. 6, South Platte division.—This district comprises all lands watered from the Boulder and its tributaries and Coal Creek. Decrees have been rendered in this district establishing the priority and amount of appropriation of sixty-two ditches and canals, which claim a total appropriation of 180,405 customary inches, or 4,698 cubic feet per second. Measuring flumes have been built in a few of the ditches in this district, but none of them have been rated.

District No. 7, South Platte division.—This district includes all lands watered from Clear Creek and its tributaries. The priority of appropriation of the ditches and canals in this district were established by decree of the court dated October 4, 1884. There are about sixty ditches which claim an appropriation of 1,180 cubic feet per second. No measuring flumes have been placed in the ditches in the district, and consequently none have been rated.

District No. 8, South Platte division.—This district comprises lands watered from the Cherry Creek, Plum Creek, and South Platte River and their tributaries, except Bear Creek above water district No. 2, and below the forks of the north and south branches of the South Platte River. The rights of appropriators have been established in this district by decree of court. There are one hundred and ten ditches and canals which claim the right to the use of 2,481 cubic feet of water per second. The abstract of the decree furnished failed to give the name of the stream from which the appropriations were made. The orders of priority are numbered consecutively to correspond with dates, without regard to the streams from which the appropriations are made. No preserving flumes have been built in the ditches of the district, and consequently none have been rated.

District No. 9, South Platte division.—This district comprises all lands watered from Bear Creek and its tributaries. The rights of the appropriators of this stream were established by decree of the court of the second judicial district, dated February 4, 1884. There are twenty ditches and canals, which appropriate 437 cubic feet per second, and six reservoirs, which appropriate an additional amount of 215 cubic feet per second. Measuring flumes have been built in some ditches in this district and these have been gauged and rated. It is estimated that there is a greater area of land irrigated from the streams in this district and more private reservoirs built with holding capacities, according to the amount of the water supply, than there is in any other stream in the State. Bear Creek, like other streams in Colorado, rises early in spring, but does not hold out through the main irrigating season. To tide over summer and fall emergencies several private reservoirs have been built and improved, without which many of the finest farms in district No. 9 would not be in existence.

Division No. 10, *Arkansas division.*—This district comprises all lands in El Paso County that are watered from Fountain Creek and its tributaries. The right of priority of appropriation of one hundred and four ditches and canals have been established by decree of the court of the fourth judicial district. The total capacity claimed by owners of these ditches is 780 cubic feet per second. No measuring flumes have been built, and in consequence no ditches or canals have been gauged or rated. The uncertainty of the water supply and the unintelligent division in times of scarcity have done much to retard the progress and development of agriculture in this district, and to render farming a somewhat precarious occupation. Probably no district of the State is in greater need of increased water supply, and the people of El Paso County are agitated on the subject of storage reservoirs.

District No. 11, *Arkansas division.*—This district comprises all the lands within the limits of Chaffee County, and contains about 1,130 square miles. There are fifty-one ditches and canals in this district recorded in the office of the clerk of Chaffee County, and these claim an appropriation of 2,366 cubic feet per second.

District No. 12, *Rio Grande division.*—This district comprises all lands irrigated from ditches taking water from Saguache Creek and its tributaries. No legal adjudication of water-rights in this district has yet taken place.

District No. 13, *Rio Grande division.*—Water district No. 13 comprises all lands irrigated by ditches taking water from San Luis Creek and its tributaries. No decrees have yet been rendered in this district concerning the right of appropriation of ditches and canals.

District No. 14, *Rio Grande division.*—This district comprises all lands irrigated from ditches taking water from La Garita and Carner Creeks, in Saguache County. There are fifty-one ditches and canals in this district, which, according to the decree of the court of the sixth judicial district, appropriate 4,407 cubic feet of water per second.

District No. 15, *Arkansas division.*—This district comprises all lands in Custer County, and that portion of Fremont County south of the Arkansas River. It was created in 1880 by General Pitken, on the application of citizens of the district and contains an area of about 1,398 square miles. The irrigable lands of this district lie mainly in the Wet Mountain Valley. No decree has been rendered establishing the rights of claimants to the use of the public waters.

District No. 16, *Arkansas division.*—This district comprises all lands irrigated by ditches taking water from Greenhorn Creek and its tributaries. This district was created by General Pitken in 1880. No record of the adjudication of the rights of claimants in this district has been received by this department, and no report. District No. 16 is one of the smallest in area yet created. The waters of the Greenhorn have their source in the low range of mountains of the same name. The supply is very limited, there being no storage reservoirs of sufficient importance yet constructed to impound the surplus waters of this stream and increase the irrigable lands.

District No. 17, *Rio Grande division.*—This district comprises all lands irrigated from ditches taking water from La Gara, Alamosa, and Spring Creeks. These waters have their source in the low and extreme end of the San Juan Mountains. The supply is often very limited and insufficient to meet the demands made by all the claimants during the main irrigating season. No decrees have been rendered concerning rights of claimant and the amount appropriated.

District No. 18.—This district comprises lands in La Plata County, irrigated from the waters of the Rio Mancos River. The source of the Rio Mancos is in the La Plata Mountains; it is a tributary of the San Juan River and joins the latter at the southwest corner of the State. There is no record of the number of ditches in this district, or the amount of water appropriated. It is not included in any water district yet created. The water commissioner divides the water in June and July, without decree of court to guide or protect him.

District No. 19, *Arkansas division.*—This district comprises the lands irrigated from the Purgatoire above the head of Purgatoire Cañon. No decree of court has been rendered establishing the right of claimants and the amount of water appropriated.

District No. 20, *Rio Grande division.*—This district comprises all that portion of Rio Grande County that lies east of the main range, and between ranges 4 and 7, New Mexico meridian, consisting of a tract of land 12 miles east and west by 30 miles north and south. This district is a rectangular tract of land extending across the Rio Grande lying mainly on the south side. It is difficult to discover a reason for creating this district regardless of the direction and extent of the drainage. No decree has been rendered establishing the rights of claimants to the use of the public waters.

District No. 21.—This district comprises all lands in La Plata County irrigated from waters of Las Animas River and its tributaries. No statement of ditches has been filed in the office of the clerk of the court, nor any return from the water commissioner. District No. 21 is not included in any water district yet created.

District No. 22.—This district comprises all lands irrigated by ditches taking water from the Jomichi Creek and its tributaries. It is not included in any district yet created, has no water commissioner, and no decrees of court have been rendered establishing the right of claimants to the use of the public water.

District No. 23.—This district comprises all land from Ute Creek, Sangrede Christo Creek, and Frinchera River and their tributaries. There is recorded in the office of the State engineer an abstract of statements of twenty-three ditches and canals. These ditches claim the right to the use of 85 feet of water per second. No water commissioner has been appointed.

District No. 24.—This district comprises all lands in Conejos and Costilla Counties, irrigated from ditches taking water from the Rio Grande. No record of ditches has been filed, and no decree of court been rendered establishing the right of priority and amount of water appropriated, and no water commissioner has been appointed.

District No. 25.—This district comprises all lands irrigated by ditches taking water from the Conejos River and its tributaries. Decrees of court have established the order of priority and furnished the data from which the capacities in cubic feet per second of sixty-two ditches and canals have been computed. They appropriate 1,612 cubic feet of water per second. The water commissioner has reported that the appropriators have been able to settle the division among themselves.

District No. 26, *Arkansas division.*—This district comprises all lands irrigated from ditches taking water from the Saint Charles River. This district was created by Governor Grant on the 19th of January, 1884, and is the last district formed. The right of claimants and the amount of water claimed have not yet been adjudicated by any court. No report has been made by the commissioner for this district.

COLORADO CURRENT METER AND METHOD OF DISTRIBUTING THE SAME.

To complete the discharge of a river or canal it is necessary to determine with accuracy the area of the cross section at the point of measurement and the average velocity of the current passing the point. When the stream is small, or, as in a canal, manageable, the first measurement required, that of the cross-section, is more easily made and the shape maintained with certainty when the water is made to pass through a rectangular flume built of masonry or wood. The maintenance of the same cross-section is also important whenever it is necessary to keep a constant record of the flow, as at the head of an irrigating canal or in a river used extensively for irrigation. When the cross-section is taken in the natural bed it is quite possible to measure the water passing, but there is no certainty that the conditions then determined will be constant for a week or even a day

After the cross-section area at the measuring point is determined, it is necessary to measure the speed of the current in all parts of the cross-section, in order that the average speed may be known.

There are many more or less accurate ways of doing this in use, the most common being by means of floats, either surface or submerged, and the speed at which they are carried past a measuring distance determines the velocity of the current. Without discussing the imperfections of this or other methods more or less used in the absence of the accurate instruments employed when close measurement is necessary, a brief description of the instrument used by the engineer's department of Colorado and the method of rating it is here given. The first instrument used was a "F'teley" current meter, which was very accurate, provided the water was clear and free from weeds, grass, &c. These conditions are, however, not always found in Colorado streams and ditches, and it was found necessary to have an instrument which would be self-clearing and give accurate readings in torrents and foul water. To meet this requirement the "Colorado" current meter was designed, which acts on the same general principle as the anemometer or wind gauge, the principal change being in the shape and numbers of the caps. It has five vanes or caps revolving horizontally on an axle having bearings at the open end of a metal frame shaped somewhat like a capital W of the Roman type alphabet turned sidewise, the caps passing between the sides of the frame. On the upper arm of the frame is affixed a set of counting gears, so arranged that they can instantly be thrown into or out of connection with the vanes by means of a spring and a cord passing up the metal rod by which the instrument is held in the desired position in the water. The shape of the caps is such that floating weeds, &c., will not be retained longer than about three-eighths of a revolution.

These meters are each rated separately by moving them at known velocities through still water (which has the same effect on the meter as holding it in running water), and determining the number of revolutions made by the meter in a given time at each velocity.

Those used by the State engineer department were rated in perfectly still water in the reservoir of the Denver Water Company. To measure the velocity of the current at any given point the meter is held at that point a certain time, usually one hundred seconds, and the number of revolutions recorded. This operation can be repeated at each point of the cross-section as often as is deemed necessary, and by measuring a sufficient number of points in the current the mean velocity of the water is determined. The velocity and cross-section being known, it is easy to determine the quantity of the water passing the point in any given time, say one second. If the cross-section area is 40 feet and the average current velocity 2.35 feet per second, the quantity will be 40 multiplied by 2.35, equal to 94 cubic feet per second.

The result of the computation last described is termed the gauging of the canal or river, at the height of the water when the current velocity was measured. As the velocity increases with the increase of height of water in the flume it is necessary to make a gauging for several stages of water between the bottom of the flume and its fullest capacity, and when this has been done and the result tabulated it is possible to determine the discharge for all intermediate points. This is termed the rating.

ANSWERS TO INQUIRIES.

(1) *Give location, geographical and postal, of your colony or enterprise; area thereof, past and present; any facts bearing thereon; also size of colony, farms, and ranches.*

John C. Abbott writes from La Junta:

The Arkansas River Land, Town, and Canal Company have expended $42,500 on the canal. There are at present 10,000 acres under water. The company have purchased of the State 8,758.43 acres. The State still owns the same amount. Government reservation at Fort Lyon embraces 6,000 acres. Claims sold last season at $6 per acre. They were taken up the year before. Some Indian claims are held at $10 per acre. The head of the canal is 3 miles northwest of La Junta, Bent County.

Mark Biedell, Del Norte, writes:

Location is in Saguache County, 25 miles southwest of Saguache and 10 miles northeast of Del Norte, the nearest post-office and railroad town. The ranch consists of about 1,500 acres, bought by one of the original Mexican settlers about ten years ago. The original settlers starved out and went farther south. The La Garita Creek runs through the land from west to east and sinks below me in the valley. The soil is derived from the débris of the volcanic rocks. Outside of a little grass along the creek, it was barren. The creek in a wet season has about 1,000 inches of water.

A correspondent from Greeley Colony writes:

The colony known as the "Greeley Colony" is situated in latitude 40° 30′ north, longtitude 27° 45′ west from Washington. It is in Weld County. The post-office is Greeley, a town of about 4,000 people. What was once the colony is now the center of an agricultural district, 50 miles long and from 15 to 18 miles in width. The area of the colony proper has never been changed. It includes about 45,000 acres, 15,000 of which were purchased of the Union Pacific Railway. The remainder of the tract was preempted and homesteaded by the colonists in a body, the location of the members being determined by lot. The ranches vary in size from ten to several thousand acres.

T. C. Henry, from Conejos County, writes:

The Empire Land and Canal Company's property is located in Conejos County, upon the Rio Grande and in the great San Luis Park. We have about 100,000 acres brought under water. We are breaking up 10,000 acres now, and shall break along until 50,000 are broken. We shall have 10,000 in grain this year (1886). Under this canal is located the Old Soldier's Colony, at Logan, on the Denver and Rio Grande Railway. A Chicago colonization company has its scheme in charge. It bids fair to be a success. All the land under this canal will be cultivated in three years.

Daniel Boyd, president of the State Board of Agriculture, writes from Greeley:

In this communication I shall confine my remarks to lands under the two canals built by Union Colony, which made its headquarters at Greeley in the spring of 1870. The site of the present town, as well as all the land now farmed under its two canals, was then covered with cactus and the short grass of the plains. The canals are taken from the Cache la Poudre, the farthest north of the tributaries of the South Platte, at distances above the town of, respectively, 6 and 14 miles in a straight line; they cover, respectively, 8,000 and 25,000 acres. Farms, not gardens, near town, vary from 80 to 160 acres.

Original value of land per acre; present selling price; state whether the purchase of land carries water also; if not, rent or price of latter per acre.

Daniel Boyd, Greeley, writes:

The land, except a narrow strip of meadow land on the margin of the river, was worthless for farming, and for grazing it would only sustain one steer to 20 acres.

Without water it was not worth 25 cents per acre. We paid the railroad about $3 for alternate sections, but only in view of the possibility of its irrigation. The value of lands at a distance of from 3 to 10 miles from Greeley varies from $50 to $20 per acre. This includes right to water, subject to expense of management.

T. C. Henry, Conejos County, writes:

There are or were about 35,000 acres of Government land under canal. They were not worth taking until now that the canal is completed. They are now as valuable as other lands, being worth from $5 to $6 per acre. In addition to these prices the purchaser pays an annual rental of $1 per acre per annum for water from the canal.

Mark Biedell, Del Norte, writes:

The price of land is $1.25 to $2 per acre. There is no sale for it at present. The land company offers similar land on long time for $3 an acre. My ranch has the first right to water by a decision of the district court, made four years ago. I get plenty of water by a ditch from the Rio Grande, about 16 miles long.

D. P. Galloway writes from Wallace:

Only public domain land, subject to homestead and pre-emptions at $1.25 per acre, is vailable. The Rio Dolores runs across the narrow part of the valley, making it productive. There are no companies, as yet, to put in the water, but there is a good chance for them.

(3) *Products of land; amount, market, and average value of crops; how long planted. Are fruits grown?*

John C. Abbott writes from Wallace:

All kinds of grain and fruits. Wheat, per acre, from 20 to 50 bushels; oats, from 30 to 75 bushels; corn, from 15 to to 25 bushels; alfalfa, from 4 to 8 tons per acre. All fruits grow in abundance and are prolific, as far as tried. English gooseberries bear well the first season. Black walnuts do well. Timber of all kinds does much better than in northern part of State or in higher elevations.

Mark Biedell, Del Norte, writes:

Wheat, barley, oats, peas, potatoes, mangels, vegetables, grass, and alfalfa grow well. Threshed 2,800 bushels of grain last year and cut about 600 tons of hay. Have no market, as the transportation to Denver and the mines takes all the profit. Set out last year 3 acres of fruit trees and will set out 3 acres more this year. This is the only experiment on that scale for 100 miles around. Have raised alfalfa for ten years here.

A correspondent writes from Greeley:

We have all the field crops grown in Kansas, Missouri, or Illinois, with the addition of alfalfa. With good cultivation the following are average yields: Wheat, 25 bushels per acre, worth $1.25 per 100 pounds; oats, 50 bushels, at $1 per 100; corn, 25 bushels, at $1 per 100; hay (timothy), 2 tons per acre, at $14 per ton; alfalfa, 3 to 5 tons, at $13 per ton; alfalfa, seed, 5 bushels per acre, at $8 per bushel.

T. C. Henry, of Conejos County, writes:

The altitude is from 7,000 to 7,400 feet. Wheat, oats, barley, peas, and all kinds of vegetables common to this latitude, except tomatoes, do extremely well. Markets are in the mountains. Small fruits do well; also apples and cherries.

Daniel Boyd, Greeley writes:

Small fruits are much cultivated around Greeley and general gardening is pursued profitably. Standard fruits are not a general success. Wheat is now worth 75 cents, oats 35 cents, barley 60 cents, corn 46 cents, potatoes 55 cents per bushel. Hay in stacks on farms about $5 per ton.

(4) *Extent of irrigation works and their character; source of supply, method of distribution, cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas, irrigable or non-irrigable, occupied for cultivation, used for cattle and sheep, &c.*

T. C. Henry, Conejos County, writes:

The main canal is 80 feet wide at the head, 6 feet deep, and 32 miles long, extending through a level plain. The Rio Grande is the source. Distributed in the usual way. Cost, $200,000. Present capacity, 100,000 acres; future, 150,000. Rental, $1 per acre per annum.

Mark Biedell, Del Norte, writes:

We have a 12-foot wide ditch, 16 miles long, from the Rio Grande River above Del Norte to the ranch; also 10 miles of main ditches from the La Garita, and about 40 miles of lateral ditches. Total capacity, 3,000 inches of water; actual service about 1,500 inches. Amount used, 1 inch to the acre. Grass and grain are irrigated by flooding; trees, vegetables, and potatoes by ditches, 3 feet apart. Cost of main ditches about $15,000. The area irrigated embraces about two hundred acres of farming land and 1,300 acres of hay and pasture land.

George H. West writes from Greeley:

Irrigable land heretofore has been occupied almost wholly by farmers, but cattle and sheep men are now commencing to water large areas in order to provide feed against hard winters. Alfalfa clover has proved a wonderful forage crop when cultivated and irrigated. We cut it about three times a year here, and get about 2 tons per acre at each cutting from a good stand of it.

(5) *Climatic conditions, temperature and rainfall; results of observations, if any, as to the influence of irrigation on moisture of the earth or sky; effects of irrigation on health, fertility of soil, &c:*

Mark Biedell, of Del Norte, writes:

Altitude, 7,700 feet. Climate severe; frosts are liable to occur as late as June 9 up to June 20 in the spring, and as early in the fall as the last of August. They are sure about the 9th of September.

Summer temperature varies from up to 90° in daytime to 40° at night; in winter from 20° below zero at night to 35° above zero in daytime. Rainfall not sufficient to raise anything without irrigation. Air very thin; extremely healthy. Have noted no change in climate or moisture. Irrigation helps fertility by dissolving carbonate of soda and silicate of potash in the soil as the land gets better, after wetting for a few years.

The temperature will change 50° to 60° in twenty-four hours in winter. There are no heavy winds and it is so dry that the cold is not felt so much as in localities with heavier, moister air.

Daniel Boyd, Greeley, writes:

I do not believe that irrigation has had any perceptible influence on rainfall or much on the humidity of the atmosphere. One result of irrigation is to turn some localities into swamps. This is especially true of a surface broken into discontinuous basins. Where the surface slope from the ditch to the river is nearly uniform and underlaid with gravel the drainage is good. Some 5,000 acres of the 25,000 under our larger ditch are now worthless from excess of water and efflorescence of sulphate of soda.

George H. West writes:

Rainfall we think is slowly increasing over the region where irrigation is necessary. Irrigation undoubtedly benefits and improves the soil. We notice no detriment to health where proper waste-ways are provided for seepage and surplus water.

A correspondent writes from Greeley:

There has been no perceptible increase in rainfall or change in temperature. There has been, however, a marked change in the humidity of the atmosphere. Fogs prevail now during the summer months, a phenomenon never met with on the plains and formerly unknown here. I think this fact accounts in a large measure for the almost universal prevalence of the belief in an increased rainfall. So far as my observation has extended, irrigation has exerted no deleterious influence on the health of this region except in a few localities which defective natural drainage has rendered marshy. Where there is good natural drainage, and water is not used to excess, the sediment transported by the water in irrigation increases the fertility of the soil.

T. C. Henry, of Conejos County, writes:

The elevation is such that the air is very dry and rarefied. Ours is a delightful and equable climate, with but little rain except in July and August. Irrigation has had no appreciable effect on the rainfall or health.

The following statements were made in reply to earlier circulars of the Department:

Hon. George A. Crawford, of Gunnison City, writes:

Land in the Gunnison Valley averages about $5 per acre. The area irrigated is about 60,000 acres. The Grand River Ditch and the Pacific Slope are corporate property and sell water. The other ditches are taken out by farmers for their own use. The following are the works now in use (1885):

(1) The Grand River Ditch, in Grand River Valley, covering about 40,000 acres around Grand Junction (town). Cost about $150,000. It is 35 feet wide, 3 to 5 feet deep, and 26 miles long; has "lateral" 20 miles long, 20 feet wide, and 3 feet deep.

(2) The Mesa County Ditch, 8 miles long, 24 feet wide, and 3 feet deep. Cost, 15,000. In Grand River Valley at Grand Junction.

(3) The Pioneer Extension, an extension of the Mesa County Ditch. Projected from Grand Junction Valley to the lower end of the valley. About 1 mile is completed, 12 feet wide, 3 feet deep. Will be 15 miles long, and will cost $10,000 to $15,000.

(4) The Pacific Slope Ditch about Grand Junction supplies the town. Is 9 miles long, 5 feet wide on bottom, 3 feet deep, and cost $14,000.

(5) The Independent Ranchman's Ditch below Grand Junction, 15 miles long, 12 feet wide, and 3 feet deep; cost about $15,000. There are other ditches up Grand River; on Plateau, White Water, Kohuah, and other creeks.

We rate water by the inch. It is estimated that an inch of water under a 5-inch pressure will irrigate an acre. About 140,000 acres may be reclaimed in addition to the 60,000 already under ditch, making 200,000 in all.

Ansel Watrous, of Fort Collins, writes:

There are eighty-one ditches and canals in this (Larimer) county, fifty-three in the valley of the Cache la Poudre River, and twenty-eight in the valleys of the Big and Little Thompson Creeks.

The average duty of water there is 1 cubic foot per second for each 55 acres. Our works are generally held as corporate property. Irrigated land is worth from $30 to $60 per acre. The area now (1885) under water is 135,000 acres.

A. E. Blunt, of Fort Collins, writes:

The amount of land under water is 300,000 acres, valued at $910,000. The service of water, 1.44 cubic feet per second for 80 acres, or 1 inch for every acre. Two to 4 inches deep at an irrigation is all we ever use.

The following are the irrigation works of the district:

Name of county.	Length.	Name of county.	Length.
	Miles.		*Miles.*
High Line	30	Eaton	72
No. 2	25	Larimer County	80
Mercer	10	Big Thompson	35

There are other smaller ditches.

J. W. Colmar, of Westmore, Custer County, writes:

There are no canals or large incorporated ditches or reservoirs or artesian wells in the county. All ditches are small, and are either owned by individuals or neighboring farmers.

Prof. Elwood Mead, civil engineer, occupying the chair of physics and irrigation engineering at the State Agricultural College, writes as follows:

I cannot refrain from congratulating you on the wisdom and good judgment which originated your forthcoming report. Few persons who have not made special inquiry into the subject have any conception of the importance which this feature of our agriculture promises to assume. Not only is the desert being made to blossom, but in no other section of the Union has the writer met with an agricultural population so contented and hopeful or more prosperous.

The fact that agriculture by means of irrigation has achieved a success never anticipated by the pioneers, is indeed the great menace to the rapid and prosperous development of this interest. Parties who settled on, and began irrigating from our mountain streams ten and fifteen years ago, expected to possess the earth and the fullness thereof for the remainder of their natural lives. They cannot realize the change, and resent both the crowding in of new comers, and the attempt on the part of the State to regulate and control the distribution of water as an unwarranted interference. In some localities this has led to much hard feeling, and expensive and useless litigation.

At Dolores, La Plata County, my present address, is located one of the most important irrigation enterprises in the State. The water is taken from the Dolores River by a tunnel 1 mile long; thence it follows a cañon 4 miles, whence it emerges into a valley, 35 miles long by 15 miles broad, and 1,000 feet below the river bed.

George H. West, of Greeley, writes of leading irrigation enterprises as follows:

Pawnee Ditch and Improvement Company.—Canal 23 miles long; cost $86,000; ditch covers 30,000 acres; farms 40 to 400 acres each.

The Sterling Irrigation Company.—Canal 10 miles long; covers town of Sterling; 7,000 acres; farms 40 to 100 acres each.

The South Platte Land and Irrigation Company.—Canal to cover 15,000 acres, not completed; water taken from the Platte River.

The North Platte Irrigation and Land Company.—Water taken from the North Platte River; canal covers delta between North and South Platte Rivers. The ditch is 28 miles long.

The Pueblo Land and Canal Company.—Water to be taken from the Arkansas River; ditch 60 miles long. The work commenced early in 1885. Estimated cost, $500,000.

Mr. West sends the following table of yields and markets:

Products.	Amount per acre.	Value. per 100 pounds.
	Bushels.	
Wheat	20 to 40	$1 25
Oats	40 60	1 20
Corn	30 80	1 20
Potatoes	100 600	90
Barley	20 40	1 30

Market: Denver and mountain towns, Saint Louis, Kansas City, and New Orleans; flour sent as far as Boston.

Fruits (small) are grown everywhere; apples, plumbs, grapes, cherries, hardy kinds, do well; peaches do not succeed.

THE COLONY OF GREELEY.

J. D. Buckley, civil engineer, of Greeley, sends the following valuable sketch:

Union colony is situated in Weld County, State of Colorado. It was located in the spring of 1870, and the town of Greeley was laid out and building and other improvements commenced at the same time. The town is located in sections 5, 6, 7, and 8, township 5 north, range 65 west of the sixth principal meridian; latitude 40° 25′ north, longitude 27° 48′ west from Washington; elevation above sea level, 4,800 feet. At the time the colony and town were located the whole country was, with few exceptions, in its natural state, no improvements having been made except in a small way along the river. A few small irrigating ditches had been built to water portions of the low bottom lands, and sufficient farming had been done by the early settlers to demonstrate the fact that good crops of all kinds usually grown in this latitude could be raised successfully.

The mesas or uplands were regarded as worthless for farming purposes, and only valuable for grazing, many of the best informed expressing the opinion that large and long irrigating canals to water the higher lands would be a failure. In support of this view it was said that the water would seep out and be lost before running in a canal any great distance, and that the land would be quickly exhausted if farmed, and various other reasons why upland farming would be liable to prove unsuccessful were pointed out.

Notwithstanding all the uncertainties that must be encountered, the projectors of "The Union Colony of Colorado," located in the Cache la Poudre Valley, purchased the land they required from private owners and the Denver Pacific Railway Company, homesteaded and pre-empted Government land, laid out the town, and proceeded to build irrigating canals to water the same. About 2,600 acres of land was bought of private owners for $28,000 and 9,300 acres of the railway company for $31,000.

The colonists contracted with the railway company for all the land owned by them lying within the colony limits at an average price of $3 per acre. The Government land was acquired by the colonists under the homestead and pre-emption laws. The total amount of land originally occupied by the colony was about 30,000 acres, and remains about the same. Soon after locating the colony built a fence some 40 miles in length, inclosing all their lands including the town. This fence is still maintained, having been legalized by an act of the State legislature and being managed by a fence company. Each piece or parcel of land pays an annual tax for its maintenance, the annual assessment being about $16 for each 80 acres, and in like proportion for larger or smaller tracts. No stock of any kind is allowed to run at large inside of this fence, and none have found it necessary to fence their premises, either in town or outside, except for their own convenience. The colony originally divided the land owned by them outside of the town limits into lots of 5, 10, 20, and 40 acres each, according to their proximity to town, and deeded them to members, with perpetual right to water from the irrigating canals, for $150 each.

Other members bought land of the railway company for $3 per acre or homesteaded or pre-empted Government land. To these the colony sold right to water in perpetuity for $150 for each 80 acres. All water rights are taxed annually a sufficient amount to pay for superintendence, maintenance, and improvement of the main canals, generally from $12 to $24 annually for each 80 and in proportion for smaller subdivisions. Few of our farmers have more than 160 acres; generally they have 80, and in some cases as low as 40 or even 20.

The land occupied by the town, some 800 acres, originally cost the colony about $10 per acre, or $8,000. It was subdivided into about fifteen hundred lots of suitable size and sold to members at an average price of about $300 for each ($50 for corner and $25 for inside lots), making about $45,000 as the amount received by the colony for lots. The cash value of these lots is lawfully $300 each, making $450,000. The outside or farming land originally cost members about $5 per acre with water, and is now worth on an average $25 per acre cash, with recent actual sales at $30 for land with no improvements except plowing and ditches, including water right, the colony having long since sold all the land and water owned by them and transferred all their right in the main canal used by the farmers to a corporation composed of farmers operating under it. This company issued its stock to the water right-owners on receiving a deed for their interest, each share of stock representing water for 10 acres. In 1878, when this transfer was made, the par value was $40 for each share, making the value of an 80-acre water right $320. In 1881 the price rose to $100 per share, and it now sells at $100 to $125. This stock has actually cost the original owners about its par value, $40 per share. When land is sold including water, the stock is transferred. Nearly all the larger canals are now owned and managed by corporations who have power to levy and compel payments of assessments and divide the water equitably among the users, thus preventing nearly all the trouble which formerly attended the management of the earlier canals. The water costs the farmer the same whether he is situated near the head or at the terminus of the canals, and the same principle has been adopted in the management of the subditches or laterals, as it has been found that no canal from which a number of individuals receive their water can be successfully operated without a competent head.

Union Colony constructed two irrigating canals and one for power and irrigation. The first canal built was for the purpose of supplying the town and adjacent lands lying along the south side of the river. This is called canal No. 3. This canal was taken from the river about 6 miles west of town, and was run on a grade or fall of about 3 feet per mile. Its original size was 8 feet in width at head, and somewhat smaller opposite town. Its length is 10 miles. It terminates on the delta between the Platte and Cache la Poudre Rivers. As originally constructed it would carry about 50 cubic feet of water per second. Original cost about $10,000. It has since been enlarged and improved, its present capacity being over 100 cubic feet per second. Cost to present time, including dam at head, about $25,000.

The second canal built by the colony was taken out the river, about 15 miles west of town, for the purpose of watering the farming lands north of the river. As originally constructed it was 10 feet in width on the bottom at the head and for the first 5 miles, and gradually diminished in size towards its terminus, its total length being 26 miles. Grade or fall, 3.2 feet per mile; capacity, 110 cubic feet per second. It was calculated to water some 20,000 acres of land. Its first cost was $25,000; has been enlarged from time to time, its capacity now being 585 cubic feet per second. It will furnish water for 25,000 acres in cultivation, with the usual variety of crops. Cost to date, $80,000, or about $3 per acre for land watered by it. It is now 25 feet in width on bottom at head, and for the first 10 miles carries water 4.6 feet in depth, and is 30 miles in length. The number of water rights of 80 acres each is 320, giving over 1.8 cubic feet of water per second for each 80 acres, less about 10 per cent. for evaporation and seepage, or about 1.6 cubic feet per second for useful effect. As new land in wheat requires about 1 cubic foot of water for each square foot of surface for first watering, it would take over twenty-five days to water 80 acres with one water right, but generally only a portion of the tract is sown or planted the first year and less water is required after the first thorough irrigation.

Very much depends on the surface quality of soil and subsoil, and amount of natural moisture in the ground, so that no very definite information can be given as to the amount of water necessary to irrigate a certain piece of ground. It is our experience that a cubic foot of water per second will water from 50 to 60 acres of land sown or planted with the usual variety of crops. In town more than double that quantity of water is used, as the more a stream of water is divided up the less ground it will water. Our farmers find it to their advantage to use two or three water rights when irrigating a favorable piece of ground by changing with their neighbors. The Cache la Poudre River, from which the colony ditches are taken, generally furnishes the most water when most is needed. There is generally sufficient snow or rain to start crops in the spring and keep wheat and oats growing until the 1st of June.

During June and July the maximum quantity of water is flowing in the river, and it is during these months that most of the crops must be watered. The amount of water flowing in the river each day is ascertained at a gauging station located above all the canals, and the amount or proportion of the water to which each is entitled being known, the district commissioner or superintendent is enabled to divide the water equitably to all. The river or district commissioner is not usually called on unless there is a short supply of water, which usually occurs in the latter portion of the season. The water commissioner on each canal divides the water to each subditch or lateral, and the users divide it among themselves. Since the present State laws regulating the division and distribution of water were enacted and put in force, very little trouble has arisen in regard to the use of water for irrigation purposes.

The maximum amount of water flowing in the river each year is very variable, ranging from less than 2,000 to over 6,000 cubic feet per second. As the canals taken from the river have a capacity and use for over 3,000 cubic feet per second, it will readily be seen that there is an element of uncertainty as to water supply and the future extension of the irrigation system. Water has already been appropriated and canals built sufficient to water over 200,000 acres in this valley, and it is not probable that this amount will be very materially increased. The total amount of water flowing in the river during the year would water more than double this quantity of land, but it can only be utilized by a system of storage reservoirs. Comparatively little has as yet been done in the way of storing water in the State, and it is not probable that much will be done for many years to come. Some natural depressions or basins of moderate capacity are used for this purpose where they chance to be available, but no purely artificial reservoirs worth mentioning have as yet been constructed.

The great expense of building and maintaining large reservoirs makes it extremely improbable that our water system will be much extended in this way. Reservoirs to be of any use must be situated above the land to be watered, and where constructed in this vicinity on a small scale the land lying adjacent to them has generally been spoiled by the seepage. The parties owning land which is damaged by such seepage usually compel the owners of the reservoirs to stop using them for storing water. The influence of irrigation on the humidity of the atmosphere is very slight, being almost entirely local, and on new lands, outside of the irrigating canals, farming would be as certain to prove a failure as it would twenty years ago.

If any climatic change ever occurs in this locality whereby the humidity and annual precipitation is permanently increased, it will not be due to the feeble efforts of man. The annual precipitation in this locality is from 12 to 20 inches, the average being 15 inches for the last twelve years as observed in Denver. The destruction of the timber in the mountains west of us will probably injuriously affect our water supply during the irrigating season by leaving the snow exposed to the direct rays of the sun, causing it to melt quickly and run off. The advance of the farmers from the East with a solid front, plowing up the entire surface, may produce some change, but such a change would be without a precedent. If our annual rainfall was double what it now is, farming could not be carried on successfully, except in favored localities, the evaporation being so rapid during the growing season. In town, which is situated on what is called the second bench or bottom, some 25 feet above the level of the river opposite, gardens and lawns must generally be watered every week or ten days in dry weather, and our farmers do not stop irrigating on account of an occasional shower. Much as an increase of natural moisture may be desired in this dry and arid region, we can give no good reasons for expecting it.

Although this town and surrounding country has been irrigated for many years, raising the ground water, in portions of both town and country, nearly to the surface, causing it to partially fill many of the cellars under dwelling houses, no malarial diseases have been prevalent. The surface soil is generally a clay or sandy loam, from 5 to 10 feet in depth, underlaid with clear sand or coarse gravel 25 to 30 feet in depth, which affords a good natural medium for the rapid transmission of surface water to lower levels, but within the last few years more water has been run on the surface in town than the natural drainage will carry away; and we are now constructing deep drains to prevent the water from rising above a certain level. Said drains are located from 8 to 10 feet below the surface and have a good fall to the river. Our farmers do not keep much stock, as they do not now, as formerly, have outside range for them. Alfalfa is grown by nearly all our farmers and yields heavily. It is usually cut three times, giving from 4 to 7 tons per acre annually.

The usual variety of crops is raised, wheat, corn, oats, and potatoes being the principal ones. Wheat is still the main crop, and the quality and yield are generally good. It produces on an average over 25 bushels per acre, when properly put in and attended to. Average of all sown, about 20 bushels. Corn is quite extensively grown, and yields from 20 to 40 bushels per acre; oats about the same, and potatoes from none to 100 bushels per acre, much depending on soil, season, watering at proper time, blight, bugs, &c. In town and vicinity market gardening is successfully carried on. Of fruits, strawberries and raspberries are the ones mostly grown for profit. Standard apples are a failure, but most varieties of crabs do well. It would be difficult to give the aggregate amount and value of all crops raised in this colony without having the report of the State census, taken last year, which is not now available. Nearly all the land in the colony has been farmed continuously for the last ten years, and much of it longer, but its fertility does not seem to decrease.

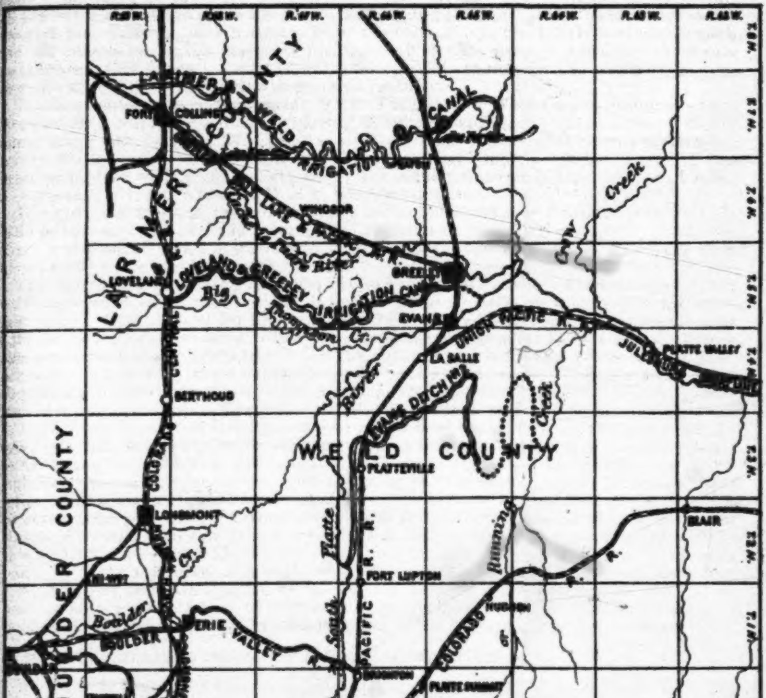
Crops when properly rotated do as well now as when the land was first broken. Scarcely any fertilizers are used on the farming land, and straw is usually burned to get it out of the way. The water used in irrigating the land carries a great amount of fertilizing matter, which is evenly distributed over the surface, fully replacing what is taken from the soil by the crops grown on it; and it is the general opinion of those most conversant with the subject that the soil is practically inexhaustible.

REPORT FROM THE PLATTE LAND COMPANY.

Mr. S. J. Gilmore, the manager, writes the Department as follows:

OFFICE, 456 LARIMER STREET.
Denver, Colo., January 18, 1886.

I have received your circular asking for information regarding irrigation and colonies. Finding it difficult to answer your questions in regular order, I prefer to give you the information in a general letter. There are four large irrigation enterprises in Colorado, located between Denver and Fort Collins, which have been completed principally by Scotch capitalists, and usually known in this State as the "English Company." The first and largest of these, and probably the largest in America, is the Platte Canal (otherwise called the High Line Canal), which begins in the cañon of the Platte River 20 miles south of Denver, and extends from there in a northeasterly course a distance of 83 miles, including one main branch of 13 miles. This canal has cost, in round numbers, $750,000, and is estimated to carry water for 50,000 acres. Its capacity is 1,184 cubic feet of water per second of time. The original value of the lands per acre was $2.50. The present selling prices, including the perpetual right to receive water every year from the canal, subject to a reasonable rental, range from $25 to $150 per acre, according to proximity to Denver. Good farming lands 10 miles from Denver are worth $25 to $50 per acre. The rent for water is $1.50 per acre for regular farming purposes, and for small tracts of 5 and 10 acres, used for market gardening, the price is $2 per acre. The basis of supply is in the ratio of 1 cubic foot of water per second of time for 53 acres. The principal products are wheat, oats, barley, alfalfa, or lucern, some Indian corn, and vegetables of all kinds that grow in this latitude. Small fruits, such as strawberries, raspberries, and blackberries, are raised most successfully and in large quantities. As this district is new, nothing can be said regarding apples, pears, and peaches, except that considerable numbers of trees have been planted within the past year or two. This canal is equipped with a telephone line. It is arranged in divisions similar to those of a railroad, and on each division, during the irrigation season, there is a foreman who is intrusted with the care of the division and the distribution of the water from the canal. Each foreman has telephone communication from his division to the general office in Denver, and to the manager's residence and the residence of the chief engineer in the same city. Each of these foremen is required to ride to the end of his division and back once a day during the irrigation season, which I may say is from the 1st of May to the 1st of October. There


R.69 W.
R.68 W.
R.67 W.
R.66 W.
R.65 W.
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R.62 W.
LARIMER COUNTY
WELD COUNTY
BOULDER COUNTY
JEFFERSON COUNTY
ARAPAHOE COUNTY
DOUGLAS CO.
FORT COLLINS
LARIMER & WELD IRRIGATION CANAL
WINDSOR
GREELEY
EVANS
LA SALLE
LOVELAND
LOVELAND & GREELEY IRRIGATION CANAL
Big Thompson Cr.
Cache la Poudre River
BERTHOUD
LONGMONT
Crow Creek
UNION PACIFIC R.R.
JULESBURG
PLATTE VALLEY
EVANS DITCH No. 2
PLATTEVILLE
South Platte River
FORT LUPTON
Running Creek
Box Elder Creek
HUDSON
PLATTE SUMMIT
BRIGHTON
ERIE
BOULDER
Boulder Cr.
BOULDER VALLEY R.R.
COLORADO CENTRAL R.R.
COLORADO & BURLINGTON R.R.
DENVER PACIFIC R.R.
DENVER
GOLDEN
MAGNOLIA
BOX ELDER
KANSAS PACIFIC R.R.
KIOWA
BLAIR
MORRISON
ACEQUIA
MELVINA
PLATTE CANON
HIGH LINE CANAL

MAP

Showing the Irrigation Works, Canals & Ditches, with Lands of the

PLATTE LAND CO.

S Mis 15 49 2

are large outlets in the canal (which are usually known as penstocks), at which places the water flows out of the canal through clay pipes of 18 inches in diameter; at the outer end of the pipes the water is regulated by sluice gates. The water is delivered into laterals, which are made by the farmers and frequently a dozen farmers are all interested in one main lateral, from which they draw water into sublaterals as it passes their farms. About 15,000 acres of land are now farmed under this canal and the area is increasing with reasonable rapidity.

The next enterprise of importance is the Larimer and Weld Canal, which is about 30 miles long and is capable of irrigating 25,000 acres of land. There are now 22,000 acres under cultivation. This canal is situated 6 miles north of the town of Greeley, where the members of the famous "Greeley Colony" mostly reside. Farming has been carried on with great success there, the principal crops being wheat and oats. The average yield of wheat is 20 to 22 bushels per acre.

The next and third of these enterprises is the Loveland and Greeley Canal, which is 25 miles long. It extends from the mountains to the town of Greeley, and will carry a volume of water sufficient to irrigate 20,000 acres, of which there are now about 6,000 acres in cultivation.

The fourth and last enterprise is the Platte Valley Canal, which has been completed a distance of 20 miles, and will be extended 15 to 20 miles farther within the next few years. Irrigation under this canal was begun only this season, and there are now 5,000 acres under cultivation. The canal will carry water for 20,000 acres. Before the last three named canals were built the value of the lands was not to exceed $2.50 per acre. They were of no value except for grazing purposes. The construction of the canals increases the value of the lands immediately to about $10 per acre, exclusive of water privileges. The water privileges are then sold at prices ranging from $10 to $15 per acre, thus making the cost of the land together with the water $20 to $25 per acre. Water rights are sold from this canal at the rates above named, subject to an annual assessment of $10 to $15 on each water right. A water right is what irrigates 80 acres. Under this plan of disposing of the water, no rent is charged, and when all the water rights have been sold on the basis of 1 cubic foot per second for 53 acres, the canal will be turned over to the persons who have purchased the water rights, who will then own it and operate it as they please. The average rainfall in this district varies from 12 to 15 inches per annum, including melted snow. It is supposed by quite a number of superficial thinkers that the rainfall has increased considerably, but an investigation of rainfall statistics will not prove this. Irrigation has not been practiced long enough here to have any perceptible effect on health. I inclose herewith a map showing the location of the four canals herein referred to.

In another communication Mr. Gilmore writes:

Farms near Denver, under the Platte Canal, range from 10 acres up to 200. Ten miles from the city farms are from 80 acres to 640 acres in extent. Under the other three canals farms range from 80 to 640, average probably about 160 acres. Non-irrigable land in Colorado, or land to which a water right is not attached, is of no value except for grazing; and as it takes a large acreage to graze a full-grown animal (estimated at from 15 to 40 acres, according to character of grass), its value is not to exceed $2.50 per acre. With water right attached, the same land would be worth $15 to $30 per acre, where value is not directly influenced by some favorable surroundings, such as town or city.

Mr. Gilmore sends the following table showing clearness, &c., of the atmosphere at Denver for thirteen years past:

Months.	Average for thirteen years.			
	Clear.	Fair.	Cloudy.	Sunny.
	Days.	*Days.*	*Days.*	*Days.*
January	16	11	4	28
February	13	12	3	27
March	14	11	6	28
April	10	13	7	25
May	9	15	7	28
June	13	13	4	29
July	12	15	4	30
August	12	14	5	30
September	17	9	4	29
October	16	10	5	29
November	16	10	4	28
December	15	13	3	29

Average moisture, 12 to 15 inches annually. Temperature moderate. Lower altitudes seem to have heavier falls of snow. Same influences (the Rocky Mountains) that deprive us of rains prevent heavy snows, and the heat and cold do not seem to be so intense as in the more humid atmospheres. Statistics do not show that moisture has increased from the sky. Irrigation of course increases moisture in the earth very much, especially where unskillful farmers think they cannot put too much water on their crops. Irrigation does not seem to have had any effect at all on health. Soil is very productive where irrigation is properly practiced.

EFFECTS OF CULTIVATION ON HUMIDITY.

Henry McAllister, jr., a well-known citizen of Colorado, made an address at the State Forestry Convention of 1884, held at Colorado Springs, from which the following interesting testimony is taken:

> I do not believe that the great plains can be forested until the rainfall is increased. I do believe it will be increased by the gradual but sure cultivation of the soil in Kansas and Nebraska, and the march of civilization to the west from the Missouri Valley. Cultivated fields, by holding the water that falls upon them, act as reservoirs. The settlement of Illinois, Kentucky, and Tennessee has greatly increased the rainfall in Iowa and Missouri. The settlement of the last two States has largely increased the rainfall in Kansas and Nebraska. When the writer came to Colorado in 1872, he was told by the officials of the Kansas Pacific Railroad that nothing would ever be grown west of Salina, as the rainfall was insufficient. Now, immense crops of corn, wheat, and oats are grown every year far to the westward of that town, about 98° 30′ west from Greenwich. At places in Nebraska along the line of the Union Pacific and Burlington and Missouri railroads the rainfall has greatly increased within a few years. The buffalo grass is being killed off by moisture, where nothing else could grow ten years ago. I am sure that a field of corn exercises the same influence upon the atmosphere that a forest of like extent does, and it only requires three months to grow it. In a few years there will be an irruption of corn and wheat fields upon the eastern borders of Colorado, and stall-fed cattle and sheep will take the place of our range stock clear up to the base of the mountains. Forests of deciduous trees will beautify the rolling prairies.

KANSAS.

THE TREELESS PRAIRIES AND THE WATER SUPPLY.

The following report, made by Mr. Frank E. Jerome, of the Record, Russell, Kans., was prepared at the request of this Department. After a general statement as to the effect of cultivation on treeless regions, Mr. Jerome says:

> My remarks upon this subject are restricted to Western Kansas, where the advancing settlement and cultivation have proved of wonderful benefit to a portion of the treeless land that had been designated as a barren desert. By this cultivation the humidity of the atmosphere has been increased; tree planting is slowly but surely becoming successful; drouths, once so frequent in this region, are becoming of more short duration, and millions of bushels of small grain successfully raised demonstrate the practicability of farming operations in this region. And as the humidity increases, we notice that the chalk beds are surely changing, the alkali beds are disappearing, tame grasses are obtaining a foothold, and every other indication of a prosperous future is appearing. It is gratifying also to notice the increase of rainfall, the bursting out of new springs in places where they were totally unlooked for heretofore, dry wells becoming filled with water, and other indications of a like character. But while this is true, these changes, though sure, are slow, and the popular demand is for some immediate help that will more rapidly assist the workings of nature and provide means whereby agricultural pursuits can be a certainty; and these means being out of the reach of individuals, the strong support of the Government is the only one that can possibly be appealed to.
>
> We notice in looking over the meteorological conditions of a region, that in some manner there appears to be a common union between the ground and rain storms,

This is most apparent in contrasting the difference between a prairie and a wooded country, and it is by studying these phenomena that we are enabled to arrive at a correct solution of the matter. The soils of deserts, where rain seldom or never falls, is composed of arenaceous beds, with strata of slate or shale underlying them. The water deposited by a rain storm penetrates this sand and gravel, and is carried off on the surface of the underlying slate or shale, leaving not a vestige behind. Where this shale has a large depression and the water remains, an oasis is created in the midst of the burning waste, that is renowned for its fertility. In prairie countries where the soil has become hard by centuries of exposure, the water cannot penetrate through, but flows from its surface into the creeks and rivers, and in a few hours evaporation has reduced the surface to its former condition, and like the desert it has had no beneficial results. What is true in this last case applies with similar force to the condition of Western Kansas in 1859, and any beneficial results since then are solely due to settlement and cultivation. In treeless prairies we notice something similar in the action of the undercurrents to those in deserts, but the surface is far different. Western Kansas, embracing something like 50,000 square miles in 1871, was very nearly covered with buffalo grass—a grass with broad, spreading roots that, matting together near the surface, shed water with almost the precision of oil cloth, no moisture whatever penetrating to any great depth, no matter how heavy the rainfall. At the present day, under cultivation, this grass has begun to disappear, though the greater portion of the indicated region remains unchanged, owing to the sparseness of settlement. It is interesting to note the changes produced as this grass gradually disappears. As the rain pours upon this grass, the action of a given quantity appears to be detrimental to its growth, the blades grow weaker and smaller, the roots become loose and brittle, and as the plant dies, the moisture creeps into the ground, penetrating deeper and deeper each year. During the summer months, when the upper soil has become heated from the sun's rays, this moisture is steamed up to the roots of the plant, which makes the decay of the grass more rapid. The grass that takes the place of the buffalo grass is the blue joint, a grass capable of absorbing and retaining a vast amount of water.

It is plain that the remedies needed to transform a desert to a fertile region, and a prairie country like Western Kansas from an arid to a humid region are entirely opposite. The desert requires some substance to be mingled with the gravel in order to prevent the water penetrating, while in Western Kansas one of the great changes needed is the extinction of the buffalo grass, so that moisture can thoroughly penetrate the soil and decompose the underlying shale. Where this has been done in this State a marked increase in the humidity of the air has been noticed. It is very apparent that a large share of this increase has been produced by cultivation of the soil and extinction of the buffalo grass, together with the planting of trees, largely encouraged by the Government in the form of timber-culture entries.

The economic value of the soil is largely due to its formation, the larger portion being of the cretaceous period, and represented by the three groups, Dakota, Benton, and Niobrara. The soil is a rich loam, from 3 to 12 feet in thickness, and lies uniformly upon a stratum of yellow clay of varying thickness. This yellow clay contains lime, magnesium, and aqueous iron, which in large portions form the magnesium limestone of this region (magno ferro calcite). These rocks are porous in structure, and, like a sponge, absorb water, which in heated, drouthy weather they give out to the roots of plants, making them thrive where under any other circumstances they would die for want of moisture. This is why some crops grow and do well for weeks without a drop of rain to nourish them through a drouth. But, as in all new countries, it is not entirely safe to rely upon these changes which are being made, which at best are extremely slow, and the great need exists for a water supply at ready demand for this region which can be used with benefit now in assisting agricultural pursuits and making tree-culture a permanent success. One thing above all others is necessary to this end, and that is irrigation. In the southwestern part of this State, in some localities, irrigation is successfully accomplished, but in the upper half of the State it is impracticable, owing to the lowness of the beds of the streams compared with the surrounding country.

The only way in which irrigation can be successfully used in the western part of the State is either by artesian wells or artificial ponds. It is a noteworthy fact that with the increase of humidity, as indicated, the volume of water in the streams has been steadily increasing and becoming more uniform than heretofore; but while this is true, and while the water in these streams would be nearly sufficient for irrigation if it could be used, it cannot as a general thing be reached for this purpose.

The water sources of Western Kansas are represented chiefly by the following streams: Republican River, North and South Forks of the Solomon River in the northern part, Saline and Smoky Rivers in the central part, and the Arkansas and Cimarron River in the southern part. The stream having the largest volume of water is the Arkansas, next the Republican, then the Solomon, while the Saline, Smoky, and Cimarron are about equal. Along the Arkansas in some places irrigation is successfully accomplished, but to the best of my knowledge it is impracticable on the other streams. The volume of water in the streams is increased each spring by the melting of snow in the mountains, and also by the heavy rains which frequently visit this part of the State in February, March, and April, but it decreases as summer approaches unless heavy rain-storms prevail, when it is very common for the streams to rise out of their banks.

The question that is of vital importance to this part of the State is that of artesian wells. Should these be obtained irrigation could be successfully carried on, the humidity of the air could be rapidly increased, and the treeless prairies, with the greatest ease, could be transformed into a beautiful, fertile country, rich in everything that tends to make a country productive and prosperous. The question of artesian water has been revived in Western Kansas by the remarkable success attained at Denver, Col., it naturally being inferred that the veins of water encountered there must underlie this region.

Mr. Jerome gives an account of the well (not used on account of trouble with the contractor) at Russell, Kans., in which flowing water was obtained at a depth of 977 feet, after passing a vein of hot water and two of salt water. He also describes a gas well near Russell, one in the Solomon Valley, and one in Smith County. He then proceeds:

The lessons that the Russell artesian well and these gas wells teach, as I interpret them, are as follows:

In Nebraska, 6 or 10 miles north of the Kansas State line, and almost in a true line north and south of the wells just mentioned, I found the shale to be 170 feet in thickness. At Smith Center it is about 107 or 110 feet in thickness; in the western part of Osborne County, 105 or 107 feet; in Russell, 104 feet; south of here, in Barton County, 104 feet; in the southwestern part of Reno County, 100 feet; southwest of Sedgwick County, 97 feet, and in Sumner County, 80 feet. I mention these localities because they are in the line of the general maximum thickness of the shale, which is much thinner to the east and west of these localities. The boiling hot water encountered in the Russell artesian well comes to the surface in Sumner County and is capable of boiling an egg even in that exposed condition. I believe that a depression exists along the line just indicated with a mean width of 20 miles at the surface, and that the peculiar roaring heard in these gas wells is caused by these underground currents of artesian water rushing down the sides of this declivity, giving rise to the sulphureted hydrogen gas by attrition with pyritiferous rocks, which the Russell well shows exist below. This current of water, in falling into this depression, naturally follows this course, like the stream of a river in its bed, and is carried south, then southeast. East of this line I expect artesian water will be encountered at only very great depths, but on the western side at a comparative easy distance. The difficulty encountered at the Cheyenne wells is plainly perceived when it is understood that this water runs in veins, and not in sheets, and moreover the locality chosen is on a ridge, geologically speaking, and the water would naturally course around it, instead of to it. The attention of the Government is more particularly called to the advisability of boring for artesian water at the following places where indications exist: Russell, Gorham, Hays City, Ellis, and Wa Keeney, on the Kansas Division, Union Pacific Railroad, and at Cawker City, Gaylord, Kirwin, Norton Center, Osborne City, and Stockton, on Central Branch Union Pacific Railroad. All of these places give similar indications, and I feel confident will produce favorable results. Along the line of the Atchison, Topeka and Santa Fé Railroad I have not been able to explore, and can make no personal report for that section of the State. I am almost under the impression that a large vein of artesian water trends from the west, going northeast toward Atchison, and it may be from this source whence Chicago derives its wells. One of the many reasons I have for believing in the existence of artesian water at the localities mentioned is as follows:

I have procured a sample of the rock found in the Denver artesian wells. In the Russell artesian well, at a depth of 395 feet, a 1-inch vein of this rock was encountered, which, within fifteen minutes, raised a 223-foot column of water 7 inches in diameter 7 feet. At the gas wells the same rock has been encountered in different stages, and also at the localities named above. It is true that these small strata do not belong to the true vein, but they are valuable from the fact that they are spurs or offshoots from the parent vein and indicate its presence. No geologist can by any rule or system locate exactly the source or depth of artesian water, as it cuts through geological strata with impunity and often appears where it is least expected, a fact that is very strikingly illustrated in the New York wells, which are encountered in some cases in the hard granite. The only way to locate the vein is to either find it, or discover a spur or offshoot from it, or from the action of water that may lie close to it.

One measure, however, which would at least transform Western Kansas into a most beautiful country would be that of artificial ponds for irrigating purposes. There is not one farm of 160 acres of land in Western Kansas, to my knowledge, that could not be thoroughly irrigated in this manner. The general surface is rolling, and ravines are numerous. It would be a very easy task to choose a place most convenient on a farm, dam up one end of the ravine or depression, and the rainwater flowing into it would in a short time produce a pond of sufficient capacity to water any and all crops that might be raised. There are many years when this pond would not be needed. Take, for example, the present year, when the crops have grown to such an enormous extent that it was impossible to harvest them completely, wheat yielding from 25 to 60 bushels per acre, and corn from 30 to 60 bushels, saying nothing of the tons upon tons of excellent prairie hay that has been cut. But it is best to be provided with ample means in case of drouth, so that crops of *all kinds* shall be permanently sure. These ponds can be successfully managed, as we have several of them in successful operation. One of these is owned by Dr. Haise of this county, who has stocked it with fish, and is finding fish culture a paying investment to combine with his pond. These ponds the first year, after being filled, will lose water by its penetrating the ground, but at the second or third year the pores of the ground have been filled and the water will remain permanently.

The aid of the Government would be beneficial in this respect in offering a bounty to every actual settler, who would make and maintain a pond of certain dimensions for this purpose, for a certain number of years, and the State could add to this such an additional amount as would pay a farmer handsomely for keeping and maintaining two or three of these ponds upon his land. With these in successful operation, tree-planting would be successful, grain of all kinds would be assured, and the humidity of the air would reach such a degree that permanent changes and favorable results would be reached, that could scarcely be hoped for under the present system in less than half a century.

THE PLAINS OF WESTERN KANSAS.

The following interesting paper and preceding summary is from the pen of the Rev. John D. Parker, post chaplain at Fort Hays, Kansas, who is also editor of the Centropos, the weekly newspaper of the place:

Inclosed please find a copy of my paper, read before the Kansas Academy of Science at the last annual meeting at Lawrence, which you solicited. Perhaps it may present a few points of interest:

(1) It gives a summary of our vegetation on the plains, presenting the results attained by the actual experience of our oldest settlers.

(2) It furnishes a meteorological summary, which *proves* the increase of our rainfall, which has been disputed by Eastern scientists.

(3) It utters a warning to immigrants of the danger of engaging in general farming in the western portion of Kansas, where multitudes have lost all their possessions.

(4) It offers the suggestion that some tree may be found in foreign countries better adapted to the great central plains of North America than any now cultivated on the prairies.

John J. Case, volunteer observer, United States Signal Service, writes me from Allison, Decatur County, Kansas, the following valuable statement of his experience and observations:

"My location here is about on the line which at present divides the semi-agricultural settlements from the strictly pastoral region. I am west of the one hundredth meridian, on the headwaters of the Solomon River. Our streams here are from 8 to 16 miles apart, and are fed by springs. I have observed that they increase in volume every night and fall during the day. I have also noted that our springs increase their flow for a short period preceding each rain-storm. The divides, or table-lands, between our streams are several hundred feet above them (over 3,000 above sea level); they yield water in wells at depths ranging from 100 to 175 feet. The constant advance to the west of the limits of successful agriculture in the State has established the fact that the climate changes, and that atmospheric humidity, quantity of rainfall, and volume of water in streams, increase as the country becomes broken by the plow. The short growth of mesquite and buffalo grass with which our plains are covered possesses little moisture, and generally dries in midsummer, thus favoring the formation of the hot winds so dreaded by the frontier farmer. The physical formation of the country has been built up under the hoofs of the buffalo. Their bones are found at all depths in our soil. They have for ages grazed and galloped in countless numbers over these plains, and have so hardened and compacted our soil that the water from our thunder-storms—our chief supply for purposes of agriculture—flows off into the streams before half of it has time to soak into the hardened surface. With the breaking up of the soil this is changed. The rainfall is all absorbed by the loosened soil, and, returning gradually by evaporation to the air, it equalizes the temperature, making the hot days cooler and our usually cool nights warmer. The hot winds, saturated with moisture, come freighted with wealth instead of ruin for the farmer. The moist vapor from the green fields of growing grain and from the damp soil prove effectual to attract and stay the course of passing clouds, which yield their fulness.

"I can refer you to Aldine Township, in the adjoining county of Norton, which, having been largely broken up six or seven years ago, has never since failed to receive sufficient rains, and to raise good crops every year, while the regions surrounding on every side, not so generally cultivated, failed to get the rains, and consequently to raise such good crops.

"Where a region is purely pastoral, as it is south and west of here, the close grazing and tramping of cattle keep back the growth of blue-joint and other large grasses, and foster the growth of mesquite, buffalo, and gramma grasses, which seem to be unaffected by drought. With the advent of the plow, however, the breaking up of large areas and consequent increase in atmospheric humidity, especially where the soil is no longer overrun and closely grazed by large herds of stock, there comes a noticeable increase in the blue joint and other large grasses, which quickly drive out the short growths, and from their succulent leafage evaporate their share of moisture to increase the climatic change.

"No irrigation has been practiced in this vicinity, our streams not having sufficient water for that purpose, and no artesian wells have been attempted. Some suggestions have been made as to trying here the Australian plan of building surface reservoirs by damming our ravines or drains to hold the water from our occasional heavy rains, but the idea has never been put in practice. The history of the agricultural occupation or settlement of Kansas has been like a description of the incoming tide. With each period of abundant rainfall and consequent good crops on the frontier comes a wave of immigration, which passes the old and makes a new frontier line. This is driven back by a year or more of dry weather and poor crops, but never so far back as the preceding line. Then follows another period of sufficient rainfall and good crops, and another wave, which overlaps the preceding one, and then part way recedes, each advance of the agricultural settlements bringing a climatic change and permanently reclaiming a part of the so-called desert. With this change in atmospheric humidity always occurs a corresponding change in the grasses, the shorter disappearing before those of more luxuriant growth."

Western Kansas, or that portion of the State lying west of the ninety-eighth meridian, comprises an area of about 40,000 square miles. People of the Eastern States have imbibed the most radical misconceptions of this territory regarding its soil, climate, and vegetation. Large numbers of immigrants have been induced to settle on these Western plains, without any knowledge of the adaptations of nature, or any adequate preparation to meet the necessities of the new country, and have lost all their possessions. Others have come with more knowledge of the country, and with a better preparation to meet its requirements, and have made comfortable homes, and are becoming prosperous and rich.

No problem is presented to the people of Kansas of more importance than this: to determine the natural resources of Western Kansas, to ascertain the adaptations of soil and climate to vegetation, and to put settlers in possession of facts necessary to enable them to make permanent and comfortable homes. I believe that under intelligent treatment, and with proper adaptations to nature, Western Kansas may become one of the richest and most prosperous portions of the West. With this in view I have treated this subject in a popular and practical way, rather than in a strictly scientific manner.

The physical features of Western Kansas are simple and easily understood. This region consists of high, rolling prairies, interspersed with bottom-lands, and has a gentle slope toward the east and southeast. Passing from the northern to the southern limit of the State we cross six principal streams, the Republican, Solomon, Saline, Smoky Hill, Arkansas, and Cimarron. These principal streams have more than two hundred affluents, which, with countless drains, give the whole country the most perfect drainage. The soil of these high rolling prairies is mainly a rich alluvium, and, with favorable climatic influences, is adapted to all the forms of vegetation produced elsewhere in this latitude.

The meteorological conditions of Western Kansas are important in their bearing on vegetation and should be carefully studied. Fort Hays, located in north latitude 38° 59′, longitude 99°, with an altitude of 2,107 feet, affords about an average for Western Kansas. The average rainfall for the last five years has been between 19 and 20 inches. During this period the maximum temperature was 110, on July 20, 1881, with a south wind estimated at seven on the Smithsonian scale, a violent gale. I suppose this exceedingly high state of the thermometer must be caused by the hot wind being driven on the thermometer, so that it is affected, as it were, by the direct heat of the sun. The minimum temperature for the last three years was 26° below zero, occurring January 9, 1881.

The chief difficulty of the climate in Western Kansas is not so much a deficient average rainfall, as the danger existing in extremes. Now and then we have a dry year, and hot winds that destroy the crops. Hot winds will sometimes destroy the green corn in a day. At such times people shut themselves up in their houses, as they would during a simoon. The prairie grass dries up; still there is enough nutriment left in the dried grass for cattle to live on the range. But late crops, such as corn and vegetables, are utterly destroyed.

The meteorological conditions of much of Western Kansas are not advanced enough yet to admit of general farming with any degree of safety, and the sooner immigrants from all parts of the world learn this fact the better it will be for them and all concerned. Still, every year the country is growing better, the rainfall is gradually increasing, the rain-belt is traveling west from 10 to 15 miles a year, and the time is not remote when many crops in Western Kansas will be nearly as certain as in any other portion of the State. The immense area of virgin prairie broken in Kansas every year continually favors the retention of a greater amount of moisture in the soil, which, evaporating, is condensed and precipitated in more frequent and copious showers, thus gradually increasing the rainfall. At Fort Leavenworth, for nineteen years immediately preceding the settlement of Kansas, the average rainfall was 30.96 inches, while for the nineteen years immediately following, the average rainfall was 36.21 inches, giving an average increase of 5.21 inches per annum. If we divide the periods of observation into two equal parts, the twenty years' records at Fort Riley give an increase of 3.05 inches of rainfall per annum, the twenty-four years' records at Manhattan give an increase of 5.61 inches, and the seventeen years' records at Lawrence give an increase of 3.06 inches. If we express the rainfall of these three stations in per cent., the increase in the second half of these periods mentioned has been, at Lawrence, 9 per cent.; at Manhattan, 20 per cent., and at Fort Riley, 13 per cent. Western Kansas will undoubtedly experience a similar increase of rainfall following its general settlement, which vegetation already indicates in many ways; but as it lies west of the meridian forming the western boundary of the Gulf of Mexico, larger amounts of vapor will always be transported by the south winds over the eastern than over the western portions of the State, to be condensed and precipitated in rain.

The grasses of this region are varied and sufficient for stock purposes. The buffalo grass (*buchloe dactyloides*), whose roots are very penetrative, extends from the British possessions to Mexico, passing over this region, and has been the support of countless numbers of buffalo, deer, and antelopes in all seasons of the year, and also furnishes the support of the animals of the recent settler. Tame grasses, that is, timothy and clover, have not done well, but some blue grass in my yard this summer has made a vigorous growth.

Western Kansas is peculiarly well adapted to raising stock. Settlers who have turned their attention to this industry have generally done well. Cattle are turned out on the range the year round, but shelter for stock during the winter is humane and profitable. Cattle are increasing very rapidly.

The main cereals of this region at the present time are wheat, rye, and winter oats. Wheat and rye are staple productions and are quite certain crops. Probably no other portion of the State is better adapted to the production of winter wheat than Western Kansas. The golden grain (at the present writing, July 15, 1884) waves in the breeze in all directions, and will give an estimated yield of from 20 to 30 bushels to the acre. The air is full of the noise of reapers and headers, and the threshers, driven with their little steam engines, are going out in various directions for their fall work. Last year about 500,000 bushels of winter wheat were marketed at Hays City, and the estimated amount this year will be double that of last year. Sorghum is a very certain crop, and promises to become valuable under the new methods for the manufacture of sugar.

At our post garden at Fort Hays we raise the principal vegetables in great abundance. Lieut. J. A. Manley, United States Army, the officer detailed to superintend the garden, has kindly given me his experience as follows:

"We raise lettuce, radishes, and the early varieties of green peas. The later varieties are exceptional. The early varieties of eight-rowed corn, yellow and flint, grow well but the larger varities, and sweet corn, are liable to be killed by the hot winds which sometimes visit us. String beans grow occasionally, and early beets and early turnips do well. Set onions are very sure. Irish potatoes are occasional, but sweet potatoes are more certain. Salsify does well. We can raise apples, plums and cherries. Strawberries do well, and raspberries are occasional. Raspberries start well, but are liable to dry up and be small. Tomatoes are doubtful and early cabbage occasional. Watermelons grow, but muskmelons and squashes are doubtful, on account of insects, which prey on their rough leaves,

> "But tree culture is the great problem before us. If one eighth of the territory of Western Kansas could be covered with forests, it would become one of the most productive portions of our country. This question needs to be studied in the light of physical features, soil, rainfall, hot winds, maximum and minumum temperature, and the adaptation of vegetable forms to the necessary conditions of the country. We need forests for the wood and shade which they furnish, for the moisture they precipitate and retain, and for obstructions to the force of winds, which at times render our homes and stock uncomfortable, our orchards and fruit unsafe, and our crops liable to great injury. Abundant forests would doubtless prevent the hot winds, which are more destructive to crops than any other thing, and would also have a tendency to drive the tornadoes into the upper regions of the atmosphere, and render them harmless.
>
> "In arboreal culture we have many things to learn. We find that the standard trees of the Eastern States, such as the sugar-maple, beech, white and golden willows, larches, firs, and spruces, do not do well in Western Kansas."

Mr. Parker gives a general description of the trees he considers adapted or adaptable to the western plains of Kansas. These include the osage orange (*Maclura aurantiaca*); the hackberry (*Celtis occidentalis*); the ash-leaved maple (*Negundo aceroides*); the green ash (*Fraxinus viridis*); the cottonwood (*Populus monilifera*); the black walnut (*Juglans nigra*); the red elm (*Ulmus fulva*); the white elm (*Ulmus americana*); the European elm (*Ulmus campestris*); the honey locust (*Gleditschia*); the black locust (*Robinia pseudacacia*); the wild cherry (*Prunus serotina*); the ailanthus (*grandulosus*); and the red cedar (*Juniperus virginianus*). Mr. Parker adds:

> Some other kinds of trees are grown on the great plains, but these are the principal varieties. Now, amidst all these varieties we have not one forest tree that stands related to the necessities of man, as the oak does in the Eastern States. We have not one tree that is adapted to make a forest, as the great oak family is. On general principles, I believe such a tree exists somewhere in the world. Nature has wonderful adaptations. Some flowers blossom in the snow, or very near to it, and some animals live in hot springs. Would it not be a good work for the Government to look for such a tree in foreign lands? Through its multitudinous correspondents it could ascertain whether such a tree exists or not. Trees adapted to a climate such as prevails over our western prairies could be transplated to an experimental farm on the western plains and thoroughly tested by experts in tree-culture. When the right tree is found actual settlers could be supplied in small quantities, so they could begin to grow forests, and sufficient inducements should be held out to them by the State and General Government to have trees planted in suitable groves all over our western plains. Such intelligent treatment of our western prairies would convert them from their present condition into the finest and richest and most productive portion of our country.

SUGGESTIONS AS TO WATER SUPPLY.

F. E. Jerome, of Russell, writes the compiler of this report as follows:

> In your letter of inquiry you say—
>
> "(1) The Department will be obliged to you for any hints at engineering projects and systems such as you may think would tend directly to the creation of a storage, as well as a larger distribution of water.
>
> "(2) As to your (my) own views and the viewsof others about national aid toward the utilization of the larger water sources and supplies.
>
> "(3) And as to how community as well as individual and property rights can be best subserved in this matter of water uses."
>
> In answer to the above, I beg to submit the following:
>
> I do not believe that any engineering projects can be of much good as applied to any of the rivers of Western Kansas, except in the southwestern part of the State, and as I have not visited that portion I can give no report from personal knowledge. But I am well convinced that immense benefit to at least two-thirds of Western Kansas would be insured by locating various water reservoirs on the hills in that part of the State including the Blue Hills, which are at an approximate elevation of 150 feet above land in their immediate vicinity, and 250 above land within 5 or 10 miles north and south that could be irrigated in this manner. The hills extends to the western line of the State, and have an available slope sufficient for this purpose along their entire length.

The hills in many places afford a flat surface at their summit from 3 to 4 miles in width, sufficient for the location of water reservoirs of immense capacity. Troughs or ditches could be run into these reservoirs from north to south on top of the hills that would cause these reservoirs to be filled by rain or snow storms, affording a ready supply for all practical demands for irrigating purposes without further expense than constructing the reservoirs and digging ditches thereto. Where these large water reservoirs are not practicable, a Government bounty to settlers who would maintain artificial ponds on their farms, as recommended in my former report, might secure good results. These water reservoirs should all be under the management or supervision of a water inspector, whose duty should be to report annually to the Agricultural Department at Washington, D. C., on the following subjects:

(1) The humidity of the air, an observation having been taken every six months, stating increase or decrease since reservoirs were started.

(2) Condition of grasses, trees, or growing grain for the year past, as compared with former years, with suggestions for experiments that may be desired.

(3) Condition of soil, rocks, and mineral deposits, showing what changes have been observed during the establishment of these reservoirs; also the increase or decrease of water in wells, new or exhausted springs, &c.

(4) Regarding repairs needed; times and length of times water has been needed for irrigation; new ditches needed, &c.

PARTIES USING THESE RESERVOIRS.

A Government tax levied on those using water would defray the current expenses of maintaining these reservoirs and would thus make them self-sustaining and successful.

The report of the water inspector would clearly show to the Department the progress in agriculture made by this system, and would enable the Department to judge just when they should be discontinued, for the time would come when this would be made necessary by the permanent increase of humidity and the successful growth of trees and tame grasses, which would then take the place of the reservoirs in a permanent and prosperous form.

Community as well as individual rights could best be subserved, by petitions to the Department through the water inspector in order to best understand just what was needed, and the best and easiest plan in granting or refusing the matter asked for, as the case might be.

ANSWERS TO INQUIRIES.

(1) *Give location, geographical and postal, of your colony or enterprise, area thereof, past and present, any facts bearing thereon; also size of colony, farms, and ranches.*

The manager and superintendent of the Kansas Irrigation and Water-Power Company writes:

Our location is Garden City, Finney County. The number of acres under our system of ditches is about 40,000. The water is supplied by two ditches, at a cost of about $1 per acre. The number of acres under actual cultivation is about 6,000.

Edward Russell, of Lawrence in reply, says:

Our location is Finney County. The canal runs for 20 miles along the bluff on the north side of the Arkansas River, gradually rising up the bluff, as the latter slopes eastward by southeastward at the rate of 6 feet per mile, while the fall of the canal is 3 feet to the mile, until just north of Deerfield, on the Atchison, Topeka, and Santa Fé Railroad. The canal runs northeasterly at an angle of 40 degrees from the river, and terminates near the north line of Finney County.

William Harvey, Garden City, writes:

Garden City is about the center of the irrigation district in Western Kansas. Farms vary in size from 40 to 160 acres.

Burnett Smith writes from Garden City:

Garden City, Finney County, Kansas, is on the Atchison, Topeka, and Santa Fé Railroad, 60 miles from the southern boundary of the State, and 60 miles from the Colorado line. The population is 3,000 (1885). Crops have been raised for about four years.

County filling up rapidly, but is yet very new.

J. W. Gilbert, Eureka Irrigating Canal Company, Spearville, Kans., writes:

Our headquarters are at Spearville. The farms in this vicinity generally comprise 160 acres.

(2) *Original value of land per acre and present selling price; state whether the purchase of land carries water also; if not, rent or price of latter per acre.*

Burnett Smith writes:

Government land is $1.25 and $2.50 per acre. The purchase or use of water is optional with buyer of land. Water is $1.50 to $2 per acre for the season.

J. W. Gilbert writes:

The original value of land was $3 per acre (three years ago); it is now selling at $8 to $10. The purchase of land does not carry the use of water; the price of water will be $1.50 per acre for each season.

The superintendent and manager of the Kansas Irrigation and Water-Power Company writes:

The original value of the land was from $2 to $4 per acre; it is now worth from $8 to $50 per acre.

Edward Russell, Lawrence, Kans., secretary and manager of Great Eastern Irrigation Company, writes:

Land along the canal was one-half railroad, one-half Government land. The latter is mainly occupied by settlers who have not perfected title. The railroad land was held at first at $2 per acre; it now sells at $6 per acre. Price of water is separate and is $1 per inch for each season.

(3) *Products of land, amount, market and average value of crops; how long planted? Are fruits grown?*

The manager and superintendent of the Kansas Irrigation and Water-Power Company writes:

The products are wheat, corn, oats, barley, and garden products in general. Small fruits are beginning to bear successfully. Grapes in general do exceedingly well. The alfalfa clover yields as high as 10 tons per acre per annum.

Edward Russell writes:

Products thus far are, mainly, oats, alfalfa, vegetables, on which the prices have varied very much, higher generally than in Eastern Kansas, and less than in Colorado and New Mexico. The first settlement which used irrigation was in 1880. All fruits adapted to Eastern Kansas or Iowa thus far do exceedingly well.

All kinds of grain and vegetable crops are grown; we grow sweet potatoes in perfection.

Fruits are now grown. One man sold over $500 worth of strawberries last season.

J. W. Gilbert says:

General farming, small grain and corn, and very fine fruit.

(4) *Extent of irrigation works and their character; source of supply, method of distribution; cost and value of irrigation works; amount available at present and prospectively; nature of works; service per acre; any general facts showing extent of works, land areas, irrigable, or non-irrigable, occupied for cultivation, used for cattle, sheep, &c.*

Edward Russel, writing of the Great Eastern Irrigation Company's works in Finney County, says:

The main canal is 36 miles long; main branches 35 miles long. The supply is from the Arkansas River. The canal and branches cost $30,000. Lands along canal are quite level, rich, and good for raising grain, grass, or fruit. The canal can supply about 30,000 acres with water, but would require some additional outlay so to do. Present demand is far less than 9,000 acres.

The superintendent and manager of the Kansas Irrigation and Water-Power Company writes:

There are two ditches, one 40 feet and the other 20 feet wide. The cost of water is about $1 per acre per annum. The longest ditch is about 18 miles The land is well adapted for irrigation, having a uniform slope, about 8 feet to the mile.

Burnett Smith writes:

There are 50,000 acres irrigated; 12,000 irrigable under ditches already constructed and projected. The supply is from Arkansas River. Ditches and laterals are on surface. Considerable territory yet used for grazing purposes.

A correspondent writes from Dodge City:

Irrigation works commenced 8 miles west of Cimarron River. Main canal will extend to Kinsley.

The main canal will be 90 miles long, and the laterals 60 miles. The canal will irrigate 800,000 acres; cost of construction will be $600,000. About one-half is now completed.

J. W. Gilbert writes:

The canal is about 90 miles long, 40 feet average width, 6 feet deep; it will irrigate 300,000 acres.

(5) *Climatic conditions, temperature and rainfall; results of observations, if any, as to the influence of irrigation on moisture of the earth or sky; effects of irrigation on health, fertility of soil, &c.*

Burnett Smith writes:

Dry air. Elevation 2,800 feet. Rains are becoming more timely and rainfall heavier. Irrigation and cultivation are undoubtedly helpful. Country none the less healthy, and the soil is very fertile.

William Harvey writes from Garden City:

Usually dry, but the rainfall has been much greater the last two years; health good, and soil rich.

The superintendent and manager of the Kansas Irrigation and Water-Power Company writes:

The climate is cold in winter and never extremely hot in summer. The country has an altitude of about 3,000 feet. The effect of irrigation on moisture of the earth and rainfall is very marked. Watering the land cools the air and brings on rain. The fertility of the soil is increased; the health of the people is good.

Edward Russell writes:

The only record of temperature, rainfall kept for any length of time which can guide our judgment as to Finney County, has been kept at Dodge City by the United States Signal Service, 1874. The system of irrigation is too slight and recent to show any effect. That the result of it is beneficial to the soil in increasing the crops was plainly shown the past year, 1884, which was the best ever known in Western Kansas for raising of a crop without irrigation.

J. W. Gilbert writes:

We shall turn the water in our canal for the first time about May 1, 1886. It is completed as for as Spearville, the first 60 miles. The balance will be completed this season. The cost of construction will be something over $500,000.

The superintendent and manager of the Kansas Irrigation and Water-Power Company adds the following remarks:

The most important observation I have made is on the increase of moisture in the ground and the tendency to rain upon a few days' irrigating. When I first visited Finney County, in 1882, the ground was hard and dry, the grass short, and what little rainfall there was came in dashes and ran off without penetrating the soil. The fires frequently destroyed what little grass grew, and left the soil entirely unprotected from the baking sun. A fall of dew was rare. Now there is at least a more even distribution of the rainfall throughout the year; the soil is saturated; water is frequently seen on the surface, and the streams have more water in them. No doubt the settlement of the country, breaking of the sod, preventing of fires &c., have something to do with the improvement in the climate, but the settlement of the country is aided by irrigation.

In Illinois drainage has produced a great effect in protecting the farmer from excessive moisture. On the plains of the West the reverse operation should be practiced; the water should be stored and held back in every practicable way. Lakes for storage and for stock and irrigating purposes, fish ponds, breaking the soil so that the rain is absorbed more readily, and the prevention of fires, will all tend to make the country more habitable.

C. J. Jones, of Garden City, writes that—

The Great Eastern Canal has about 60 miles of main and lateral ditches, and cost $110,000.

The Kansas Canal has 20 miles, and cost $8,000. The Garden City Canal has 15 miles, and cost $6,000. The Western Canal has 16 miles, and cost $7,000. One cubic foot will water from 150 to 200 acres, and by judicious use will serve about twice that area. Our canals are generally corporations, and sell the water at about $1 per acre annually.

C. P. Safford, of Garden City, Finney County, writes of his experiences with irrigation as follows:

I purchased from the Atchison, Topeka and Santa Fé Railroad Company, April 17, 1882, 200 acres in section 13, township 24, range 33 west, Finney County, Kansas, at a cost of $10 to $12.60 per acre. The $10 land was cash. The $12.60 on six years time. Commenced to farm in spring 1883, farming about 40 acres that season, of which 28 acres were in oats mostly on sod. Raised 1,400 bushels of oats (over weight) 100 bushels of onions, 40 bushels of beets, and 35 bushels turnips. Ten acres of the 40 was farmed by Rev Mr. White, of Illinois, over seventy years of age, his crop being sweet potatoes 600 bushels, and onions 700 bushels, besides Irish potatoes and other vegetables. Paid $1 per acre for water, using it on vegetables only. Sold oats at home for 40 to 50 cents per bushel. Farmed in 1884 18 acres to winter wheat. The crop was pastured all winter and late in the spring with wild horses. Crop 450 bushels, sold at 75 cents. Thirty-five acres of oats yielded 1,650 bushels, which sold at 45 to 55 cents per bushel. Ten acres of barley yielded 240 bushels which sold at 60 to 75 cents per bushel. One acre of Irish potatoes (not a good stand) yielded 120 bushels, which sold at $1 per bushel. One acre sweet potatoes yielded 125 bushels, which sold at $1.25 per bushel. Twelve acres of millet (not heavy) yielded 1 ton to the acre, which sold at $5. Paid $100 for water in the spring, but did not use it at all on small grain. In 1885 the farm was rented. The results for that year were as follows: Wheat crop from 38 acres, pastured as before, 700 bushels, which sold at home at 38 cents per bushel. Twenty acres of oats (light crop) yielded 700 bushels, which sold at 45 cents per bushel. Ten acres of barley yielded 250 bushels, which sold at 75 cents per bushel. On a timber claim 6 miles west, I raised 25 acres of millet, getting a crop of 75 tons. It is selling now in market at $10 per ton. There was no irrigation this season.

Water is owned by companies, and purchased as wanted.

My land adjoining the addition to Garden City is selling at from $60 to $100 per acre.

Hon. Edward Russell, in letters to the Department, gives the following interesting and valuable data relating to enterprises with which he is associated. He says:

The Great Eastern Irrigation Water-Power Company is located in Hamilton and Finney Counties, Kansas. Water is taken from the Arkansas River by canal. Corporation was organized under the laws of Kansas. Capital stock is $200,000; amount invested is $50,000. Present value hard to tell, for as yet the receipts are much less than the annual expenses. The main canal is now 35 miles long, the laterals or secondary ditches being 40 miles long. The Arkansas River supplies sufficient water from the middle of May up to the close of August. Prior to the middle of May, and before the snows melt and swell the river, the water supply is small, and again for a month or six weeks about the close of summer. The area possible to serve is about 34,000 acres, with existing canal. The area of irrigated land within the counties named (1885) is about 60,000 acres. The value of raw land is $6 per acre. The area that can be reclaimed is at least 400,000 acres. The amount of service is placed by Mr.

Russell at 1.44 cubic feet per second to each 80 acres. The rental is $1.50 per acre. Service is rendered when wanted by the farmers during the season, and the water is drawn at will as yet by the farmers. The service is in flooding. As the demand increases, the service and volume of water will be more systematic. All regulations are made by the company, there being no laws in Kansas as yet governing water supply and its distribution. The whole system of irrigation is in its infancy in the State. The value of land prior to irrigation was merely nominal; now it has settled at $8 to $10 an acre for irrigable land, unimproved. As to climate, no perceptible effect as yet has been seen. Too short a period has elapsed since the first canal was dug in 1880. Water flowed in our canal for the first full season last year (1885).

Mr. Russell writes, under date of Lawrence, September 29, 1884, as follows:

First as to water supply of Western Kansas. Let us begin on the southwestern corner of the State, and we find the first stream of any size, and which at all approaches to permanence, to be the Cimarron River. This comes out of Colorado in two streams, neither of which is sure to have water in a dry year until a point is reached near where the two streams unite. After running for a few miles the water sinks till nearly 70 miles east of the west line of Kansas. From thence the stream always runs, though the water is brackish. After reaching the Indian Territory it becomes at times exceedingly salt, too much so in low water and dry weather for cattle safely to drink it if heated. Much of the way along the bottom, which is quite narrow in most places, the land is too poor for any use. It is a sort of salt or alkali land. At no point will the stream answer as supplying water for irrigation in Kansas.

There are many ponds noted on the maps by the surveyors, but in nearly every case the pond is only what on the plains is known as a buffalo wallow. They hold water only in wet weather. Water is seldom found in any of them after the 1st of August. This year has been an exception, and, as in the year 1877, there have been unusual rains.

There are also creeks noted as in the western part of Kansas, south of the Arkansas River, but none of them run or furnish any water except for a little time. They are not reliable for even stock water.

The Arkansas River next demands attention. We find west of Dodge City, at near the one hundredth degree of longtitude, that there are several irrigation canals. The one nearest to Dodge leaves the river on the north side at a station on the Atchison, Topeka, and Santa Fé Railroad, called Belfast. It is rather a switch than a station, and is by the railway 396 miles from Kansas City. This canal is now being dug, and it is hoped that it will be completed by spring. Its corporate name is the Eureka, I think, and the canal is estimated to cost over $300,000. It is under the management of the Messrs. Gilbert, of Spearville.

The question of supply from the Arkansas is one not easy to determine, inasmuch as the river does not rise till in the month of May. Prior to the rise which comes from the melting of mountain snows, it is very low, and sometimes even ceases to run as far east as Dodge City, and even as far west as Garden City. The season for cropping may thus be cut short; but from the rise in the river for six to seven weeks the amount of water is sufficient to supply many more canals than now exist. There is one question not easy to answer—and it is not one of abundance of water but of engineering—that is, to ascertain the amount of land which can be irrigated. In my judgment it is not so great as is usually stated, because of the lay of the land, and from the many ravines or arroyas which intersect the line of the land at right angles to the river, and so make the canals too expensive for profitable construction. This objection, of course, will be more or less overcome as lands advance in value.

North of the line of the Arkasas there are many streams on the maps, but none of them reach up into the mountains so as to draw water from the melting snows; and hence they cannot be relied upon for irrigation. They are intermittent streams, good some years but of little or no value in others.

For instance, the Arkansas runs at Lakin 900 feet wide and in usual volume, when the snows are melted, about 28 inches deep. It is at times deeper, and of course some parts of the river are deeper; but the average of the river will not exceed the 28 inches. The Solomon River, which rises in Thomas County, has a width in the second county east thereof—Graham County—of 20 rods, or 330 feet, and its usual depth, aside from exceedingly high water is from 4 to 20 inches, or so it is reported to me. The reporter, who has lived there some years, says he has seen it dry. Of the Smoky Hill, my reporter, who has lived there five years, says the bed of the river is from 500 to 600 feet wide, and in depth about 6 inches. It usually goes dry each year.

There has been some theorizing as to the capacity of artesian wells to irrigate the plains; but any one who will consult good authorities will see quickly it is simply impossible.

It takes about 30 inches of water to supply moisture sufficient to raise a crop, and on the plains of Western Kansas you have usually less than 15 inches. At Dodge City, the average for the past nine years is less than 20½ inches, while for six years of the time it has averaged less than 15½ inches; some years less than 11 inches.

As to climatic changes in Western Kansas, the observations have not been made long enough to be of much value. If the experience of Eastern Kansas is any criterion, it would seem that in a generation or two enough change may be established to enable the settler there to raise many things now deemed impossible; but there is one factor in the case of Western Kansas and Eastern Colorado which did not exist in the case of Eastern Kansas, and which must not be overlooked, unless we are willing to blind ourselves to the real situation, and that is the fact that through heedlessness and from other reasons the timber and foliage upon the mountain tops of the Rocky Mountains and foot-hills thereof is being rapidly stripped off, so that in a very few years the mountain tops will be bare of timber and soon thereafter of the earth with which to reclothe the tops. This will inevitably result in a diminution of rainfall and snow-fall in the mountains, and thus work adversely to the rainfall on the plains of Eastern Colorado and Western Kansas.

B. McAllaster, Land Commissioner (Kansas Division) of Union Pacific Railroad, under date of September 1, 1884, writes recommending Mr. Frank Jerome, of Russell, as a competent observer, and then says:

In a general way, the period of observations in Western Kansas (from the ninety-eighth meridian west) has been too short to base any reliable theory on; yet we all notice that the blue-stem grass (a native of the moister eastern third of the State) has taken strong hold in the central third, and is crowding out most effectually the buffalo grass, which is the characteristic genus of the dry plains. The blue stem is now found as far west as the one hundredth meridian. The annual prairie fires are becoming more and more reduced in area, and have almost ceased in the central third already. The effect seems to be beneficial; new tall grasses, and especially young timber, are taking a good, strong hold where the fires are kept out. This year (1884) the buds and young shoots of peach trees were all killed by the Dakota blizzards that swept over our State in March in the eastern third; but we have had fine peaches in all the central third and as far west as Wa Keeney, Trego County, near the one hundredth meridian.

Corn, sorghum, and millet have been raised in Gore County, about 101° west longitude.

All these facts seem to warrant the belief that the moisture of atmosphere and amount of rainfall are gradually increasing toward the western plains, but we are not prepared to assert this as a fact. It must take a century of accurate observations to prove or disprove such belief.

RECLAIMABILITY OF THE "PLAINS."

FERTILITY OF SOIL AND INCREASE OF HUMIDITY.

Profs. Samuel Aughey and C. D. Wilbur, of the University of Nebraska, under date of February, 1880, in a communication to Governor Furnass, of the same State, presented their reasons for believing that the so-called arid regions of the trans-Missouri will not always be dry. Their paper was written at the time the public-land commission was inquiring into the condition of the areas west from the one hundredth meridian. The gentlemen whose views are summarized are scientists of repute, authors and teachers of recognized capacity. Their opportunities of direct observation so well supplement these qualifications that the testimony and views presented by them must be esteemed of a weighty character. The conclusion they arrive at as against the continued aridity of the region indicated may be stated as follows:

(1) The soil embraced within the area west of the one hundredth meridian "is chemically equal to any similar area of soil taken in any part of the American continent." The professors do not include either Arizona or New Mexico, yet both are equal to the other portions of the area indicated.

(2) Water is the only element lacking to insure complete productiveness.

(3) The homogeneous character of the soil is insured by the fact that it is the result of "the decomposition of primary rocks, old sea deposits, and glacial agencies, acting through long ages over great areas of both mountains and plains."

(4) The practical question to be settled, then, is the supply of moisture.

Messrs. Anghey and Wilbur hold it to be proved beyond reasonable question that "the present rate of increase in rainfall will in a comparatively short time fit this region for agriculture without the aid of irrigation." They argued at length in the paper mentioned, as also in other publications.

(*a*) "That the actual rainfall from the ninety-eighth meridian westward, over a considerable area, is sufficient to produce successfully root crops, fruits, and the cereals." Nearly up to the North Platte the rainfall averages 26 inches per annum, and beyond that for a long distance west it amounts to nearly 16 or 17 inches. It falls, too, in the early summer, when most needed.

(*b*) That the presence of nutritious grasses proves the richness of the soil. The buffalo grass as it disappears is everywhere followed by other species, far more useful, belonging to the same family of plants as the edible grains. The spontaneity and variety of the native flora on the great plains are also indicative of the richness and adaptability of the soil.

(*c*) Holding that the moisture and rainfall are gradually increasing from east to west, Messrs. Anghey and Wilbur declare—

(1) That actual tests, taken in large number, show the practicability of "grass and grain growth in the major part of the lands of the United States domain excepting actual rocky areas."

(2) It is also shown by "the western march of grass and grain growth" in Nebraska almost to the western limits of the State, 350 miles from the Missouri River; in Kansas clear up to the one hundredth meridian and (except as to grain on the uplands, or water-shed regions, and in some parts along the valleys of the Arkansas and Smoky Hill) a long distance beyond that line, and in Dakota up to the foot-hill ranges of the dorsal mountains.

(3) That the actual increase of the rainfall is clearly demonstrated by observations taken over a period long enough to give consecutiveness to the deductions made.

After citing various authorities, Messrs. Anghey and Wilbur sum up their conclusions in the following manner:

> Observation, experiment, and the highest scientific authority demonstrate that climates in the West are becoming moister and that rainfall is increasing steadily. This increase must extend steadily until the plains east of Denver and Laramie receive sufficient rainfall to produce farm products.
>
> For these reasons we are compelled to say that any evidence of present dryness, where dryness exists, is evidence only for the present and should not be used to cover these areas with the undeserved reproach or curse of desert lands.

By the term "these regions" Messrs. Anghey and Wilbur refer to the area usually designated as the "great plains," lying between the ninety-eighth west meridian, and the higher foot-hills of the frontal range of the Rocky Mountains, though they appear to have more especially in their minds the more limited but still great basin of the Republican River, embracing a large portion of Central and Northwestern Kansas and the area contiguous thereto in Nebraska. But the facts and observations they presented in 1880 were applicable then, and are still more so now, to almost the entire area embraced within the more or less treeless and arid portions of the United States.

PROSPECTS AND PROGRESS OF ARBORICULTURE.

Hon. Robert W. Furnass, ex-governor of Nebraska, writes:

> In reply to yours concerning the permanence of growth of trees in the far west and arid regions, and how much of the desert region of the Northwest and in California with the help of irrigation we can cover with trees, will say:
>
> I am aware that in advancing my views, impressions, and belief in answer to your inquiries I find arrayed against me such eminent men and scientists as Professor Sargeant, Professor Newberry, and others, relating to characteristics of western plains and arid regions generally. While I have great respect for science, scientists, and scientific theories, I have greater for facts, founded on actual experiments. Colonel Frémont, Captain Miles, of the United States Army, and others who passed through our western prairies at an early day, reported officially, and their reports are on record, that all west of the Missouri River was barren desert, unproductive, rainless, and treeless. The men who came here to stay, the actual settlers, demonstrated by experience directly the opposite, showing that the identical spot from which some of the reports referred to were made has no superior as to fertile, productive soil. The county of Buffalo, in Nebraska (220 miles west of the Missouri River), in which Fort Kearney, whence Captain Miles made his report in 1845, was then situated, has three times carried away the first premiums at Nebraska State fairs for best agricultural products of *all kinds*, a general collection.
>
> Twenty-eight years' experience, with close observation during that time in the region of country referred to in your inquiries, warrant the asserted belief that in nearly all the country indicated fruit trees can be successfully grown without irrigation. With irrigation for a few years, until trees are well established, practically all the portions generally understood to be arid and treeless can be planted and perpetual forests secured. There are conditions, however, to all this. I do not wish to be understood as saying that any and all varieties of timber are adapted to these lands and conditions. The proper varieties must be selected and used. Then, too, until trees are large enough to produce sufficient leaves and surroundings, such as to retain them on the ground as fertilizers, trees planted will need to be fed. Nature thus provides in forest regions, and man must follow the example if success is to be obtained. The virgin soil of these prairie and arid regions is wonderfully quick and lavish in response to most delicate demands for growth of all kinds, and consequently exhausts its properties rapidly. Hence the necessity of "keeping it up."

Statistics in connection with Nebraska and Kansas commence with the date of the passage of the Kansas-Nebraska act, 1854. From that time up to and including the year 1882, a period of twenty-eight years, it is found from official statistics, with some reliable estimates to cover dates for which such statistics were not available, that there have been planted within the borders of what is now the State of Nebraska 244,356 acres of forest trees. This includes seedlings, seeds, and cuttings planted in permanent forests, groves, along highways and along streets in cities and villages. Since fires have been kept from the borders of streams and ravines, the spontaneous growth is estimated to be equal to half the area planted. Personal observation would warrant a larger estimate.

Of fruit trees planted in Nebraska from 1854 to 1882, inclusive, there were 12,083,112, of which 1,714,442 were planted in the year 1882. Grapevines to the number of 2,906,754 have been planted, fully 30 per cent. of that number being planted in 1882.

Mr. Furnass, writing of tree-planting in Nebraska for the year 1884, furnished the following figures, which, he says, "I take from official reports."

	Number planted.
Cottonwood	2,500,000
Box-elder	400,000
Soft maple	800,000

	Number planted.
Ash	250,000
Elm	175,000
Sycamore	85,000
Miscellaneous	225,000
Total	4,435,000

To this add:

Walnut seed planted	bushels..	1,850
Oak nuts	do....	250
Catalpa seed	pounds..	125

The State agricultural reports of Kansas up to 1883–'84 show the progress there in arboriculture. There have been planted since the first settlement in that State 139,995 acres of forest trees, distributed as follows:

	Acres.
Walnut	9,512
Maple (mostly soft)	13,545
Honey locust	1,916
Cottonwood	47,363
Other varieties	67,659

Planted 4 by 4, or 2,722 plants to the acre, the total is shown to be 381,066,390 trees, or, 8 by 8, 681 plants to the acre, the total is 95,336,595 trees. Average the totals and we have 238,201,993. Add for spontaneous growth (estimated) 115,610,870 and the grand total is 353,812,863 trees.

The number of fruit trees planted in that State during the same time, as shown by State record, is:

	Bearing.	Non-bearing.
Apple	3,028,100	3,590,333
Pear	97,369	164,302
Peach	5,983,140	4,089,803
Plum	293,474	339,516
Cherry	776,498	756,576
Total	10,178,581	8,940,530

Grand total, 19,119,111.

Of the forest trees it is claimed that at least one-half of the whole number of acres has been planted west of the ninety-eighth meridian, west longitude.

EFFECTS OF CULTIVATION.

L. C. Wooster, of the State Geological Survey of Wisconsin, writes in vol. 4, pp. 73–79, as follows:

> While studying the causes of an evident increase in rainfall upon limited areas over the plains of Colorado, irrigated for five or six years and planted in trees and small grains, it occurred to me that vegetation has contributed to this good work by restoring to the atmosphere water that is running below the surface. The roots of many trees penetrate the ground to a depth of 10 to 20 feet and more, in search of water, pushing downward until they find it. It is not necessary for the plant to send its roots to the water-bearing layers for water, for the soil is kept more or less moist through capillary attraction, by which the water is made to rise slowly to the surface, there to evaporate. The quantity of water thus restored to the atmosphere is said to be quite large, even from tracts barren of vegetation. Plants very much hasten

this process, as they are able by roots to approach very near, if not to penetrate the water-bearing strata. Met or arrested by the roots, as the case may be, the water is drawn by osmose through root, stem, and branch to the leaves, from whence a large proportion is evaporated to the atmosphere. Professor Gray says that a sunflower plant, a little over 3 feet high, with about 40 square feet of foliage, &c., has been found to exhale between one or two pints of water per day. A fair-sized forest tree possesses between 100,000 and 200,000 square feet of area in foliage. Assuming that the evaporation from each square foot of its surface is two-thirds as rapid as from the same in the sunflower, over one thousand barrels of water would be poured into the atmosphere by the tree during each season of growth.

POSSIBLE HOMES FOR FIFTY MILLIONS.

H. M. Thompson, of Lake Preston, Dakota, spoke of the Great Plains and tree-planting thereon at the Forestry Congress, held in Montreal, as follows:

> The Great Plains extend from the southern limits of the Staked Plains in Texas northwardly about 20 degrees of latitude to the Saskatchewan River and Hudson Bay, and westward to the foot-hills of the Rocky Mountains, from an irregular east line, commencing in Texas, running through the eastern part of the Indian Territory, Eastern Kansas and Nebraska, Western Iowa, the Bigwoods of Minnesota and the Red River of the North, the average breadth from east to west being about 10 degrees of longitude and the total area comprising about 950,000 square miles. If all this possessed a propitious climate and all the soil was susceptible of cultivation, "the area would be sufficient to make 3,800,000 farms of 160 acres each, and could support a farming and pastoral population of 50,000,000.

"THE NEW AGRICULTURE."

Mr. A. N. Cole, of Wellsville, Allegany County, New York, has for some years been engaged in a system of uniform drainage, subterranean irrigation, and fertilization applicable to all mountainous or hilly sections, having a firm dry or hardpan subsoil; and in a recently published book, "The New Agriculture, or the Waters Led Captive," he gives some very surprising results of his mode of irrigation by terracing and ditching.

He stores his water below the frost line in trenches lined with stone taken from the cultivated lands. Mr. Cole repudiates the generally accepted theory that winter irrigation in the Northern States is impracticable, and details his own experience to prove that at any and all points in the New England and Northwestern States and the Canadas, a series of trenches constructed along inclines, from 3 to 5 feet deep, will hold the autumn rains so deeply down as to keep them during the winter at spring-water temperature.

Mr. Cole, in detailing his success in the new system of irrigation and storing the falling waters and the melting snows, proves that the virtue of irrigation in reclaiming sterile lands, such as he experimented on, cannot be doubted or overestimated. His products of fruits and vegetables, marvelous in size and quantity, all of which he attributes to his mode of farming, may be regarded as the result of the new departure in agriculture. Of course the circumscribed scale on which he produced these results must be considered in any attempts to introduce his system upon the almost unbounded tracts that are included in the farm lands of the West.

GENERAL REMARKS.

Irrigation of land is an art that existed for many centuries previous to any authentic written history. The traditions of the Chinese people are very ancient, and irrigation is mentioned in their earliest history as extensively practiced. In Egypt, Syria, and the ancient kingdoms of Eastern Asia agriculture depended almost wholly upon irrigation, and still so depends in those countries where the people have survived the political changes of thousands of years. The irrigation of gardens, vineyards, and fields is frequently mentioned in the Scriptures; one of the earliest books speaks of it, and one of the prophets refers to "furrows of the plantation." The systems adopted in California, Texas, New Mexico, and Colorado are of ancient origin and are copied from ancient models. They are not the best, but they are cheap and easy of construction. The settlement of the drier regions of our territory adds another instance to those of past history. The actual history of irrigation in the United States begins with the construction of the Pacific railroads.

The enormous sums expended by the British Government in India, in irrigating works, and the profit derived from them will serve to sustain the arguments put forth by Mr. Cole and others, that while Great Britain is engaged in India not only in the construction of reservoirs for the storage of the waters and streams, but for gathering in the rains and dews for the purposes of irrigation, spending millions annually in such works, and in keeping them in repair, our own country, possessing vaster domains than any nation of the world, and of incomparable value, has only to enter upon her own possessions and, by trenching her mountain sides, beget reservoirs as enduring as the foundations of the earth.

The argument for Government ownership and control of streams and other water sources available for irrigation has much to support it in the practice of foreign countries, as will be seen in the accounts of their laws in relation to waters presented in the next chapter.

POSSIBLE EVILS OF IRRIGATION.

The late Hon. George P. Marsh, for many years United States minister to Italy, in an exhaustive article on "Irrigation, its Evils, the Remedies, and the Compensations," treats on all the phases of this important subject. In this article Mr. Marsh refers to the customs and laws governing the use of water in every country of Europe. The methods of accumulating and distributing the water of precipitation, and of flooding springs and streams for agricultural purposes, are readily accessible, and in the practical employment of the system our engineers and the ingenuity of our people will, he says, no doubt overcome any special difficulties arising from the peculiar geographical and meteorological features of our territory. The social, legal, sanitary, and financial aspect of the subject in its application to extensive tracts of cultivated land are not familiar to the American public. He says, cautions of a not altogether obvious nature are more needed than instruction on points of practical method, or of adaptability to particular branches of agriculture. He points out the evils and difficulties of the practice of irrigation, and suggests precautions against the occurrence of these evils and the means of palliating them where they are to some extent inevitable. In the introduction of new systems of industrial or rural occupation in a scale large enough to affect the rights and interests of whole classes of the population, equal regard should be paid to the good of every class, and on all such occasions the moral, social, and sanitary consequences of great changes in the habits and employments of large bodies of the people is of more consequence than the merely financial results. In this as in most questions of political economy, is encountered the great enigma of the right relation between capital and labor, and there are not many instances where these relations are more unsatisfactory than in the employment of irrigation on the great scale in which it is practiced in many parts of Europe. Mr. Marsh says the tendency of irrigation in the Old World as a regular agricultural method is to promote the accumulation of large tracts of land in the hands of single proprietors, and consequently to dispossess the smaller land-holders. Where a district derives its supply of water for irrigation from a single stream or lake not practicably inexhaustible, the interests of production require that the husbandry of the entire district be administered in a uniform or harmonious system, and consequently that the control of the source of water supply be vested in a single head; for it is obvious that each land-holder cannot be allowed to draw off at his pleasure and appropriate to his own use the whole current or such parts of it as may suit his convenience. The cause, capacity, and channels of division and of final discharge must be determined by some common principle, and adapted to the branches of husbandry best suited to the soil and climate. The agricultural economy of each farmer must remain substantially fixed and invariable, and even so simple a thing as the rotation of crops would be almost impracticable because it would be impossible to change the whole system of supply. The canals of diversion and distribution once established the net-work must remain immutable, "as the arteries and veins of the human system." The measurement of flowing water and its diversion between different occupants are matters of extreme complexity, and jealousies and dissensions often arise between neighboring claimants in regard to the ascertainment of the quantity rightfully belonging to each and the amount actually withdrawn by each from the common source of supply. The consequence of these interminable vexations is that the poorer or more peaceably disposed land-holder is obliged to sell his possessions to a richer proprietor, and the whole district gradually passes into the hands of a single holder, family, or corporation. In the large irrigated plain lands of Europe real estate is accumulated in vast tracts of single ownership, and farming is conducted on a scale hardly surpassed in England or even on the almost boundless regions of our own West. In illustration of this Mr. Marsh states that ten years ago a single proprietor exhibited at an agricultural fair at Modena one hundred yoke of oxen from his own estate. There are doubtless, he says, considerable economical advantages in the system. The unity of administration tends to increase production as well as to diminish the cost, but the evils more than counterbalance this advantage. Pliny the elder complained eighteen hundred years ago that great farms had been the ruin of Italy. Next in importance to the moral and social aspects of the system comes the question of the effects of irrigation on the health of the population employing it in certain branches of agriculture where water is largely used. The fact is established that the miasmatic exhalations are highly deleterious. The rice grounds of Lombardy are almost as destructive to health as those of Georgia and other Southern States. All irrigation, Mr. Marsh says, except where the configuration of the surface and the character of the soil are such as to promote the rapid draining of the water, or where special precautions are provided against its influence, is prejudicial to health. The increased dampness of the atmosphere is injurious to the respiratory system in some localities, and in others the exhalations from the watered soil and moistened manure tend to develop malarious influences and aggravate, if not occasion, febrile diseases. Mr. Marsh says in a foot-note:

> There is no doubt the insalubrity of Rome is greatly aggravated by the abundantly irrigated gardens within the walls of that city, and the increased prevalence of malarious fevers in the neighborhood of New York and other American cities is due to increased extent of market gardens, and consequently of irrigated lands in their vicinity.

Mr. Marsh notices the purely physical evils which he regards as in many cases inseparable from this system of husbandry, and says the first and most obvious effect of withdrawing water from its narrow natural channels and distributing it over the surface of the earth is a great increase in the humidity of the soil watered, a like increase in the evaporation from it, and a corresponding reduction of the atmospheric temperature, as in other cases of evaporation. The water imbibed by the earth is generally estimated at about one-seventh of the quantity applied. This may not be sufficient to affect the consistence of the soil to a serious degree, but of the remaining six-sevenths the portion not carried off by evaporation, employed to irrigate lands at a lower level, or discharged into running streams or lakes, frequently produces a very prejudicial effect on the soil of adjacent lands over which the water flows or into which it percolates. Thus, he says, the infiltration of the superfluous water from the rice grounds of Lombardy sometimes renders the lower fields adjacent unfit for any other husbandry to a distance of miles from the land flowed for watering the rice. The division of brooks and rivers and the final discharge of the current by remote outlets tends to deprive the district originally watered by it of their proper supply, and while on the one side considerable tracts of land are sometimes drenched with superfluous moisture, on the other, water courses large enough to drive mills and other machinery may be laid dry and their fish destroyed, and even the subterranean conduits from their beds which fed the springs and wells at lower levels may cease to flow.

Irrigation always compacts and hardens the soil, and frequently to a very inconvenient degree. This, of course, increases the labor both of plowing and the subsequent tillage with hoe or cultivator, and farmers are tempted to rely too much on the fertilizing power of irrigation, and consequently to use little manure, a liberal application of which renders land less liable to become hard and tenacious by watering. A general opinion prevails that water employed for irrigation dissolves some of the fertilizing ingredients of the soil, and carries them with it in its flow or percolation through the adjacent fields into which it escapes. This opinion was controverted by Liebig, who taught that none of the material constituents of vegetation were thus abstracted by water, and that view has been confirmed by other observers. But later experiments appear to show that the doctrines of Liebig and his followers are not strictly true, for mineral and vegetable substances, which enter more or less into the food of plants, have been detected in the field, drains, and other currents from cultivated soils. There is, however, no satisfactory evidence that land is impoverished by irrigation, though the consistence of the soil may be sometimes affected injuriously. The increase of the natural humidity of the soil provokes the growth of aquatic weeds, and in all freely irrigated lands the borders of the channels of distribution are fringed with water-plants, in spite of all efforts to destroy them. In many localities irrigation cannot be carried on upon a great scale without the construction of large reservoirs. The objections to these arise from the fact that it is almost impossible to make the retaining dams or walls sufficiently secure to prevent the waters from ultimately bursting their barriers, and overwhelming the country below with ruinous desolation. Works of hydraulics are full of examples of such calamities.

The quality of the grain roots and other vegetables cultivated by irrigation is a point of importance, and Mr. Marsh says he has not found the meal of Indian corn or other cereals produced by irrigation less sweet or less nutritious than that produced on unwatered fields. There are, he says, economical obstacles to irrigation, as it is seldom practicable without considerable outlay. Dams, dikes, artesian boring-machines, pumping-machines, reservoirs, aqueducts, and canals are some of them indispensable where irrigation is employed at all extensively. The ground must be prepared to permit either a flow over it or its gradual obsorption and infiltration, and a good deal of labor is required in the way of grading before irrigation can be practiced with advantage. On the Alps irrigation is practiced almost up to the limit of perpetual frost. The water of the melting snows at its low temperature is conducted immediately over the grass. There is danger, too, of entering into the system without previous careful inquiry as to the sufficiency of supply, and this involves experiments varied and long continued to determine. There is another suggestion to make in estimating the economical value of irrigation—namely, that in some parts of our own country production is now over-abundant, and needs repression rather than enlargement. Mr. Marsh says: "From all this it will be obvious that considerable evils attend the practice of field irrigation, and they would be sensibly felt in its introduction in a country which stands in no special need of such a resource for increasing its agricultural production." The object of Mr. Marsh in pointing out these evils has been to inculcate the necessity of caution in attempting a revolution in our agricultural methods, but by no means to discourage careful study of the subject, or judicious experiment in appropriate localities.

He points out the necessity of taking especial care that water shall not be allowed to stagnate and poison the air. Hilly and winding slopes admit of a simple and efficient mode of irrigation, or a substitute which is not available on level soil. This method has been practiced with success in many parts of the United States, where it is known by the name of "circling." It consists in horizontally terracing the slopes, or furrowing them with the hillside plow, and leaving the surface permanently in this condition.

The duties of the general and local Governments of the United States in this branch of rural economy are by no means confined to the simple protection of nature's waters from private encroachment. Governments ought to take steps for collecting and diffusing all knowledge on the subject, and by encouraging and aiding experiments and by special inquiry into the physical condition and capabilities, the wants and the means of all our territory. Much of the practical information needed may be gathered from European experience, and by the study of the methods employed in those exceptional parts of our territory where irrigation has been long practiced.

Mr. Marsh, speaking of the stupendous net-work of canals lately constructed by the British Government in India, says:

> There are serious objections to the assumption of such burdens and responsibilities by republican government, but there are insuperable objections to any other system.
>
> The literature of European legislation, customary law, and judicial action on this subject is voluminous enough to form a library of itself, and of late years much has been done to lighten the labors of research on water questions, and to facilitate the application of law by codification and completion of digests and compends by private jurists.

Mr. Marsh says he is thoroughly convinced, after much observation and inquiry, that irrigation may be immensley extended among us with great commercial advantage, and that by reasonable prudence, and, above all, by a sufficient exercise of moral courage by our rulers, nearly all the evils which ordinarily attend the practice may be avoided or at least greatly mitigated.

WATER AND IRRIGATION LAWS.

Below is given a careful summary of the water and irrigation laws of the several States and Territories embraced within the dry area of the United States, and also those of ancient Rome, and of Italy, France, Spain, and Mexico.

CALIFORNIA.

Irrigation districts may be formed under general laws, and by-laws may be adopted and trustees elected by a majority vote.

The trustees may survey and locate the ditches and estimate the costs, and upon the presentation of their report to the board of supervisors of the county, the necessary assessments may be made. A list of assessments and of the land assessed and the names of the owners must be filed in the office of the county treasurer, and the assessments are thereafter a lien upon the land assessed.

The trustees must keep accurate accounts of all expenditures and all contracts, which shall be at all times open for the inspection of persons interested. The necessary property may be purchased and held.

The trustees may acquire by condemnation the right to any running water not already used for domestic, irrigating, milling, or mining purposes. They may have the right of way, and may take materials for the construction, maintenance, and repair of ditches, from lands outside as well as inside the district. Parties may, with the consent of the board of supervisors, undertake the drainage and irrigation of their own lands on their own responsibility without the adoption of by-laws or the election of trustees. By special act certain described territory in the counties of San Joaquin, Stanislaus, Merced, and Fresno are made an irrigation district, called the West Side Irrigation District. The qualified electors of this district elect five commissioners, an assessor, a tax collector, and a treasurer.

The board of commissioners has general control of the irrigation interests of the district, makes necessary contracts, employs the necessary officers and workmen, fixes the price of water, makes by-laws and regulations, constructs the necessary works, and may issue bonds of the district not exceeding $2,000,000.

The Modesto Irrigation District was formed by special act, of a part of the county of Stanislaus. The district may choose directors, issue bonds, make surveys, lay out routes, and have the right of way. The bonds are not to increase the rate of taxation, but the increased revenue caused by the increase in the value of the land irrigated shall be applied to the payment of the interest and principal of the bonds. The title to the property shall be in the district. Surplus water may be sold for any purpose. By act of March 29, 1878, the office of State engineer was created. It is the duty of this officer, among other things, to make surveys, investigate the problem of irrigation, divide the lands into their natural districts with reference to the different sources of supply and the courses of the beds of the streams, study the best means of irrigating each district, and give his opinion and advice to such persons as may be interested in irrigation.

By act of March, 1880, the boards of supervisors fix the rates at which water shall be sold, and any company charging higher rates forfeits its franchise to the county where the excessive rates are charged.

In Los Angeles County the matter is regulated practically by a superintendent of irrigation, chosen for two years, and three water commissioners, chosen for one year at general elections.

In San Bernardino County a time-keeper may be employed by any irrigation district to see that water is not unlawfully used. In case any person fails to pay his proper assessments, the time-keeper may sell so much of his water time as is necessary to pay the amount due. By special acts boards of water commissioners have been created for each of the counties of Tulare, Siskiyou, Merced, and for the city of Los Angeles. Their duties, which are defined by statute, are substantially the same as those of like officers in other counties mentioned.

NEVADA.

Any person not engaged in working ores who corrupts the waters of a stream so as to injure it for domestic or agricultural purposes is guilty of a misdemeanor and punishable by fine.

Any person desiring to construct a ditch or flume shall have recorded in the office of the recorder of the county or counties through which it is to pass a statement, duly acknowledged, showing name of ditch and its location and a plot of the proposed route or position. Ditches have the right of way, on proper compensation having been paid, but they must not interfere with prior vested rights.

UTAH.

Whenever the public necessity requires it, the county court may organize the county, or a part of it, into an irrigation district, and the land holders therein may use the water brought into the district according to their respective needs, provided they pay and perform their proportion of the necessary expense and labor. They may, on due notice, elect trustees, a secretary, and a treasurer.

The trustees shall locate the ditches and estimate all costs and report to the county court.. If the report be approved by a two-thirds vote a tax shall be assessed and the ditch constructed.

The trustees have general supervision of the construction, maintenance, and regulations of the ditches; they may hold such personal property as is necessary to the performance of their duties; may sue and be sued, and may have appraised and sell any unclaimed lands that are to be benefited, and apply the proceeds to the construction of the ditches.

Lakes and ponds may be used as reservoirs, provided they are not raised so as to injure settlers upon their banks.

In case of inundation or other sudden emergency the trustees may take measures for protection.

Property and money in the hands of trustees to be used on the ditches is exempt from taxation.

Ditches have the right of way, a proper compensation having been paid.

Any person injuring a ditch or any of its appurtenances, is liable in damages and to a fine and imprisonment.

The district is liable for damage caused by the breakage of a ditch.

The rate of tax at any election subsequent to the first may be determined by a majority vote, and the tax thus assessed shall be a lien upon the tax payer's interest in the ditch and a right to use the water.

By act of February 20, 1880, the selectmen of several counties are made water commissioners, who have a kind of superior jurisdiction of the water rights in their respective counties.

They determine claims relative to the use of the water, oversee, either personally or by agents, its distribution, and determine questions of right of way, &c.

They also issue certificates showing the extent of water rights.

A person first taking water from any source of supply, or having the open, peaceable, and continuous use of the water for seven years, has a primary right therein to the extent of the reasonable use thereof.

Whenever persons having the primary right use the water for a part of the year only, the person appropriating it for the balance of the year acquires a secondary right.

The person appropriating the surplus above the average of seven years also acquires a secondary right.

Water rights may be measured in inches or by fractional parts of the whole supply. Water rights may pertain to the land or may be personal property, as the owner may elect, and a change of place shall not affect the right to use the water; but no change of place shall be made to the injury of another owner without just compensation. Neglect for seven years to use water, or keep in repair the means of conveying it, is regarded as an abandonment of the right.

Water rights are exempt from taxation, except for the purpose of regulating the use of the rights, but the increased value of the land may be regarded in making the assessments.

Surplus water must be returned to the natural channel, and any person wasting it, is liable to have his supply shut off, and to pay damages to any person injured.

Any person using water lawfully appropriated to another, or diverting the flow of water lawfully distributed, or injuring any dam, ditch, &c., is guilty of a misdemeanor.

Whenever the supply is not sufficient for all purposes, the use for domestic purposes and for irrigating purposes takes precedence in that order.

Corporations may be formed under general laws for distributing water to their stockholders.

ARIZONA.

All streams are public and available for irrigating purposes.

All holders of arable land may construct ditches, and have the necessary right of way, paying therefor a just compensation.

No obstruction of irrigation is permitted except for mining purposes.

Foot-paths across fields are prohibited, and all animals must be in care of a shepherd, in order that no injury may be done to the ditches.

All persons holding land which may be benefited by public ditches, shall furnish labor for the ditches in proportion to the amount of their land, whether they cultivate it or not; and failing to do so are subject to a fine.

Land owners and tenants interested shall elect one or more overseers, who shall have general supervision of the construction and care of ditches, shall apportion the work to be done, and the amount of water to be allowed to each person, having regard to the kind of crops to be cultivated.

In case of scarcity, users of water take precedence according to the dates of their titles.

For neglect of duty, overseers may be fined, and, for the second offense, removed from office.

Injury to ditches, or unauthorized use of water, is punished by fine and any injured party may recover damages.

All fines for violations of the irrigation laws are applied to the maintenance of the ditches, bridges, &c.

When a ditch is constructed across a public road, the owners must erect and maintain a substantial bridge, and, for failure to do so, are subject to a fine.

Plants on the banks of ditches belong to the owners of the land.

MONTANA.

The Revised Statutes of Montana, 1879, in the fifth division of general laws, Chapter XV, on corporations for industrial or productive purposes, Article I, contain provisions, the substance of which is as follows:

SEC. 271. Whenever any three or four persons form a company for constructing a ditch for the purpose of conveying water to mines, mills, or lands, for the use of mining, milling, or irrigation of lands, they shall in their certificate specify as follows: The stream or streams from which the water is taken; the point or place on said stream at or near which the water is to be taken out; the line of said ditch, as near as may be, and the use to which the water is intended to be applied. For other details of certification see section 244.

SEC. 272. Any ditch company shall have the right of way over the line named in the certificate, and the right to run the water of the stream or streams through their ditch: *Provided*, That the proposed line shall not interfere with any other ditch whose rights are prior; the water of any stream shall not be diverted from its original channel to the detriment of any miners or mill men or others along the line of the stream who have priority of right.

SEC. 273. Any company constructing a ditch shall furnish water in the way and manner named in the certificate designated to be used, whether miners, mill men, or farmers, whenever they shall have water in their ditch unsold. They shall give the preference at all times to this class of persons, the rates for furnishing water to be fixed by county commissioners or the tribunal transacting county business as soon as the ditch is completed and prepared to furnish water.

SEC. 274. Every ditch company organized shall keep the banks of their ditch in good condition, so that the water will not escape and injure any mining claim, road, ditch, or other property; and whenever it is necessary to convey any ditch over, across, or above any lode or mining claim the company shall flume the ditch, if necessary, to keep the water out or from any claim, so far as it is necessary to protect the claim or property from the water of the ditch.

SEC. 275. When any company shall organize to form a company to construct a flume, their certificate shall, in addition to details required by previous sections, specify as follows: The place of beginning, termini, and route, as near as may be, and the purpose for which the flume is intended; and when organized, the company shall have the right of way over the line proposed for the flume, provided it does not conflict with the right of any former fluming, ditching, or other company.

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SEC. 279. Any company formed for the purpose of constructing any ditch or flume shall commence work within sixty days from the date of their certificate, and shall prosecute the work with due diligence until the same is completed; the time of completion shall not extend beyond three years from the time the work was commenced; and the company failing to commence work within sixty days of the date of certificate, and failing to complete it within three years of commencement, shall forfeit all right to the route claimed, and it shall be subject to be claimed by any other company.

SEC. 280. Every corporation formed has power, first, to have succession by its corporate name for the period limited in its certificate of charter; second, to sue and be sued, complain and defend in any court of law or equity; third, to make and use a common seal and alter the same at pleasure; fourth, to hold, purchase, and convey such real and personal estate as the purposes of the corporation may require; fifth, to appoint such subordinate officers and agents as the business of the corporation shall require, and to allow them a suitable compensation; sixth, to make by-laws, not inconsistent with any existing law, for the management of its property, the regulation of its affairs, and for the transfer of stock: *Provided*, That no corporation formed shall own or hold possession of more than six hundred and forty acres of land.

SEC. 281. The powers enumerated in the preceding sections shall vest in any corporation that shall hereafter be created, although they may not be specified in the certificate; but no corporation shall possess or exercise any corporate powers, except such as shall be necessary to the exercise of the powers so enumerated.

SEC. 282. Willful or malicious damages. or interference with property of any kind belonging to any company organized, upon conviction before the county court where the offense is committed, shall be fined not exceeding five hundred dollars, or imprisoned not exceeding one year, or both, and the offender shall pay all damages the corporation may sustain, together with costs of suit.

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SEC. 285. Whenever any organized company shall not have acquired, by gift or purchase, the right of way required for the construction or maintenance of any road, ditch, telegraph, or flume, or may be affected by the operations of the same, they may present a petition to the probate judge of the county describing the lands required, giving the name and residence of each owner, and praying for the appointment of appraisers. The judge having evidence that the owners have been notified ten days previously by publication or notices in some public place in the county, shall appoint three impartial appraisers, who shall take an oath to perform their duties faithfully. Two of them shall review the premises, ascertain and certify the proper compensation to be made, as well as all damages accruing to the owners, after making a just allowance for the real benefits or advantages which the owners may derive from the construction of the road, ditch, telegraph, or flume. They shall file a certificate of their ascertainment and assessment in the county clerk's office. The probate judge upon such certificate and proof that compensation has been paid to the parties entitled to the same, or deposited to their credit, shall have a certified copy of the description of the lands and payment or deposit of compensation recorded in the recorder's office of the proper county. The corporation shall have the exclusive right of all such lands, during the continuance of the corporation, and may take possession of, hold, and use the same for the purpose of the, road, ditch, telegraph, or flume, and shall be discharged from all claims for any damage. If at any time after an actual ascertainment of compensation, the title acquired or the assessment should be deemed defective, the corporation shall proceed, and perfect the title by procuring the assessment of the proper compensation to be made to any person who has an interest in or lien upon the lands. The probate judge may authorize the corporation, if already in possession, to make payment in the manner hereinafter provided, if not in possession to take possession of and use the premises until the final conclusion of the proceedings, and may stay all actions against the corporation on account thereof: *Provided*, That the corporation shall pay a sufficient sum into court, or give approved security to pay the compensation. When possession shall be so authorized it shall be lawful for the owners to conduct the proceedings to a conclusion if the same shall be delayed by the company.

The substance of Article I, Chapter XXXIII, on rights of persons and corporations is as follows:

SEC. 731. Any person or persons, corporation or company, who may have or hold a title, or possessory right or title to any agricultural lands, as defined by the organic act, shall be entitled to the use and enjoyment of the waters of the streams or creeks for the purpose of irrigation, and making the land available for agricultural purposes to the full extent of the soil: *Provided*, That in all cases where, by virtue of prior appropriation, any person may have diverted all the water of any stream, or to such an extent that there shall not be an amount sufficient left for those having a subsequent right for such purpose of irrigation, and there shall at any time be a surplus so diverted, over and above what is actually used for such purpose by prior appropriation, such person shall be required to turn and cause to flow back the surplus water, and upon failure to do so, within five days after demand being made upon him in writing by any person having a right to the use of the surplus water, the person diverting the same shall be liable to the person aggrieved in the sum of twenty-five dollars for each and every day the water shall be withheld after the notice, to be recovered by civic action by any person having a right to the use of the surplus water.

SEC. 732. When any person or persons, corporation or company, owning or holding land shall have no available water facilities, and when it is necessary to raise the waters of the stream or creek to a sufficient height to irrigate the land, or whenever the lands are too far removed from the stream or creek to use the waters, the person or persons, corporation or company shall have the right of way through and over any tract or piece of land for the purpose of conducting and conveying the water by means of ditches, dikes, flumes, or canals.

SEC. 733. The right to dig and construct ditches, dikes, flumes, and canals over and across the lands of another shall only extend to so much digging, cutting, or excavations as may be necessary for the purposes required.

SEC. 734. In all controversies respecting the rights to water the same shall be determined by the date of the appropriation as respectively made by the parties.

SEC. 735. The waters of the streams or creeks may be made available to the full extent of the capacity for irrigating purposes without regard to deterioration in quality or diminution of quantity, so that the same does not materially affect or impair the rights of the prior appropriator; but in no case shall the same be diverted or turned from the ditches or canals of the appropriator so as to render the same unavailable.

SEC. 736. Any person or persons, corporation or company, damaging or injuring the lands or possessions of another by reason of cutting or digging ditches or canals, or erecting flumes, shall be liable to the party so injured.

SEC. 737. This article shall not be so construed as to impair, or in any way or manner interfere with, the rights of parties to such use of the water of streams or creeks as may have been acquired before its passage.

SEC. 738. This article shall not be so construed as to prevent or exclude the appropriation of the waters of the streams or creeks for mining, manufacturing, or other beneficial purposes, and the right also to appropriate the same is hereby equally recognized and declared.

SEC. 739. Any person or persons, corporation or company, who may dig and construct ditches, dikes, flumes, or canals, over or across any public roads or highways, or who may use the waters of the same, shall be required to keep the same in good repair at such crossings or other places where the water may flow over or in any wise injure any roads or highways, either by bridging or otherwise.

SEC. 740. Any person or persons offending against the preceding section on conviction shall pay for every offense not less than $25, nor more than $100, with costs of suit in civil action; one half the fine shall be paid for the benefit of the common schools of the county, the other half to the person or persons giving the information. The defendant or defendants may be confined in the county jail until the fine and the costs are paid.

SEC. 741. In all controversies respecting the rights to water, whether for mining, manufacturing, agricultural, or other useful purposes, the rights of the parties shall be determined by the dates of appropriation respectively, with the modifications heretofore existing under the local laws, rules, or customs, and decisions of the Supreme Court.

Article II deals with the regulations for the sale of water, and in substance is as follows:

SEC. 742. Any person or persons, corporation or company, having the right to use, sell, or dispose of water, and engaged in using, selling, or disposing of the same, who shall have a surplus not used or sold; or any person or persons, corporation or company having a surplus of water, and the right to sell and dispose of the same, shall, and they or it are hereby required, upon the payment or tender to the person or persons entitled thereto of an amount equal to the usual and customary rates per inch, to convey and deliver to the person or persons, company or corporation, such surplus of unsold water, or so much for which the payment or tender shall have been made, and shall continue so to convey and to deliver the same weekly, so long as the surplus of unused or unsold water shall exist and the payment or tender be made.

SEC. 743. Any person or persons, corporation or company, shall, at their own cost and expense, construct or dig the necessary flumes or ditches to receive and convey the surplus water so desired by it or them, and shall pay or tender to those having a right to the use, sale, or disposal thereof, an amount equal to the necessary costs and expense of tapping any gulch, stream, reservoir, ditch, flume, or aqueduct, and putting in gates, gauges, or other proper and necessary appliances, usual and customary in such cases, and until the same shall be so done the delivery of the surplus water shall not be required.

SEC. 744. Any person or persons, company or corporation, constructing the necessary ditches, aqueducts, or flumes, and making the payments or tenders, shall be entitled to the use of so much of the surplus water as the ditches, aqueducts, or flumes shall have the capacity to carry, and for which payment or tender shall have been made, with all the rights and privileges incidental thereto, so long as the unsold or surplus water exists and the payment or tender shall be or have been made, and may institute and maintain appropriate action, at law or in equity, for the enforcement of such right or recovery of damages arising from a failure to deliver, or wrongful diversion of the same.

SEC. 745. Nothing in this article shall be so construed as to give the person or persons, corporation or company, acquiring the right to the use of water, as hereinbefore provided, the right to sell or dispose of the same after being so used by it or them, or prevent the original owner or proprietor from retaking, selling, and disposing of the same in the usual and customary manner after it is so used.

Chapter XLV on rights of way for the development of mines, Article IV, in substance is as follows:

SEC. 886. The proprietor, owner, or owners, of mining claims, whether patented under the laws of the United States, or held under the local laws and customs, shall have a right of way for ingress and egress, for the necessary purposes, over and across the lands or mining claims (patented or otherwise) of others, as hereinafter prescribed.

SEC. 887. Whenever any mine or mining claim shall be so situated that it cannot be conveniently worked without a road thereto, or a ditch to convey the water thereto, or a ditch or a cut to convey the water therefrom, or without a flume to carry water and tailings therefrom, or without a shaft or tunnel thereto, which road, ditch, cut, flume, shaft, or tunnel, shall necessarily pass over, under, through, or across any lands or mining claim owned or occupied by others, either under a patent from the United States or otherwise, then shall the first-mentioned owner or owners be entitled to the right of way for the road, ditch, cut, flume, shaft, or tunnel over, under, through, and across the other lands or mining claims.

SEC. 888. Whenever the owner or owners of any mine or mining claim desire to work the same successfully, he or they shall have the right of way for the purposes heretofore mentioned, and if it shall not have been acquired by agreement between all parties, it shall be lawful for him or them to present a petition to the judge of the district court of the county, praying that the right of way be awarded to him or them. The petition shall be verified and contain a description of the character and extent of the right sought, the mine or claim of the petitioner, and the claim or claims, and the lands to be affected by the right, with the names of the occupants or owners. It may, also, set forth any tender or offer hereinafter mentioned, and shall demand the relief sought.

SEC. 889. Upon the receipt and filing of the petition with the clerk of the court, the judge shall direct a citation to issue under the seal of the court, to the owners, named in the petition, of the mining claims and lands to be affected by the proceedings, requiring each of them to appear before the judge on a day therein named, which shall not be less than ten days from the service thereof, and show cause why the right of way should not be allowed. The citation shall be served on each of the parties in the manner prescribed by law.

SEC. 890. Upon the return day of the citation, or upon any day to which the hearing shall be adjourned, the judge shall hear the allegations and proofs of the respective parties, and if he is satisfied that the claims of the petitioner can only be conveniently worked by means of the privilege prayed for, he shall make an order adjudging and awarding the right of way, and shall appoint three commissioners, disinterested parties, and residents of the county, to assess the damages resulting to the lands or claims affected by the order.

SEC. 891. The commissioners shall faithfully and impartially proceed to examine the premises and shall assess the damages and report the amount to the judge, and if the right of way shall affect the property of more than one person or company, the report shall contain an assessment of damages to each company or person.

SEC. 892. For good cause shown, the judge may set aside the report of such commissioners and appoint three others, whose duties shall be the same as above mentioned.

SEC. 893. Upon the payment of the sum assessed as damages, to the persons to whom it shall be awarded, or a tender thereof to them, then the person or persons petitioning shall be entitled to the right of way, and may immediately proceed to occupy the same, and to erect such works and structures, and make such excavations as may be necessary to the use and enjoyment of the right.

SEC. 894. Appeals from the assessment of damages may be made and prosecuted in the proper district court by any party interested, at any time within ten days after the filing of the report, and a written notice of the appeal shall be served upon the appellee. The appellant shall file with the clerk of the court a bond, with sureties to be approved by the clerk, in the amount of the assessment appealed from in favor of the appellee, conditioned that the appellant shall pay any costs that may be awarded to the appellee and abide by any judgment that may be rendered in the cause.

SEC. 895. Appeals shall bring before the appellate court only the propriety of the amount of damages and may be tried by the court or before a jury.

SEC. 896. The prosecution of any appeal shall not hinder, delay, or prevent the appellee from exercising all the rights and privileges heretofore mentioned: *Provided*, That the appellee shall file with the clerk of the court in which the appeal is pending, a bond with sufficient sureties, to be approved by the clerk, in double the amount of the assessment appealed from, conditioned that the appellee shall pay to the appellant whatever amount he may recover in the action.

SEC. 897. If the appellant recover $50 more damages than the commissioners shall have awarded, or the appellee shall offer to allow judgment against him to be taken, the appellee shall pay the costs of appeal, otherwise the appellant shall pay such costs.

SEC. 898. The costs and expenses of proceedings, except as herein otherwise provided, shall be paid by the party making the application: *Provided, however,* That if the applicant shall, before the commencement of such proceedings, have tendered to the parties owning or occupying the lands or mining claims, a sum equal to or more than the amount of damages recovered by the defendant or defendants, then all of the costs and expenses shall be paid by the party or parties owning the lands or mining claims affected by the right of way and who appealed and resisted the claim of the applicants.

The substance of Article I, section 1081 (Chapter LIV, on roads and highways), is as follows: County roads running parallel shall not be nearer than one mile, and upon the presentation of a petition signed by at least five freeholders of any neighborhood praying for passage to the various water-courses for stock purposes, the commissioners may at their discretion establish such passage-way. This section shall also apply to the opening and establishment of neighborhood roads running to timber.

(For other details of roads, see section 1064.)

The general laws for 1883 contain an act to punish persons for unlawfully diverting water; in substance it is as follows:

SECTION 1. Any person who shall divert from any water-course or ditch any water flowing therein, and by such diversion shall deprive another of the use of water to which he is entitled by law, and who shall refuse immediately to relinquish the water so diverted, upon demand being made by the person, or the agent of the person, to whom the water rightfully belongs, shall, on conviction, be fined in any sum not to exceed $100 or imprisoned in the county jail not exceeding three months, or by both.

SEC. 2. If any person, by force, threats, intimidation, or putting in fear with arms, or otherwise, near or upon any water-course or ditch, shall prevent or seek to prevent any person from possessing or obtaining any water which he desires for some useful purpose, or by these means shall prevent any person lawfully entitled to the use thereof from diverting the water, when and where he may desire, the person so offending shall be deemed guilty of felony, and on conviction, be imprisoned in the territorial prison not less than one year, nor more than five years.

The general laws of 1885 contain an act relative to water-rights, in substance as follows:

SECTION 1. The right to the use of running water flowing in the rivers, streams, cañons, and ravines may be acquired by appropriation.

SEC. 2. The appropriation must be for some useful or beneficial purpose, and when the appropriator or his successor in interest abandons and ceases to use the water for such purposes the right ceases; but questions of abandonment shall be questions of fact, and shall be determined as other questions of fact.

SEC. 3. The person entitled to the use of water may change the place of diversion, if others are not thereby injured, and may extend the ditch, flume, pipe, or aqueduct, by which the diversion is made, to any place other than where the first use was made, and may use the water for other purposes than that for which it was originally appropriated.

SEC. 4. The water appropriated may be turned into the channel of another stream and mingled with its waters, and then [be] reclaimed; but in reclaiming it water already appropriated by another must not be diminished in quantity or deteriorated in quality.

SEC. 5. As between appropriators, the one first in time is first in right.

SEC. 6. Any person hereafter desiring to appropriate water must post a notice in writing in a conspicuous place at the point of intended diversion, stating first, the number of inches claimed, measured as hereinafter provided; second, the purpose for which it is claimed, and place of intended use; third, the means of diversion, with size of flume, ditch, pipe, or aqueduct, in which he intends to divert it; fourth, the date of appropriation; fifth, the name of the appropriator. The appropriator shall file with the recorder of the county, within twenty days after date of appropriation, a notice, which, in addition to the facts required to be stated in the posted notice, shall contain the name of the stream from which the diversion is made, if it has a name, and if not, such a description of it as will identify it; also an accurate description of the point of diversion and reference to some natural object or permanent monument.

The recorded notice shall be verified by the affidavit of the appropriator, or some one in his behalf, which must state that the matter and things contained in the notice are true.

SEC. 7. Within forty days after posting the notice the appropriator must proceed to prosecute the excavation or construction of the work by which the water appropriated is to be diverted, and must prosecute the same with reasonable diligence to completion. If the ditch or flume, when constructed, is inadequate to convey the amount of water claimed, the excess claimed above the capacity of the ditch or flume shall be subject to appropriation by any other person.

SEC. 8. A failure to comply with the provisions of this act deprives the appropriator of the right to the use of water as against a subsequent claimant who complies therewith, but by complying the right to the use of the water shall relate back to the date of posting notice.

SEC. 9. Persons who have heretofore acquired rights to the use of water shall, within six months after the publication of this act, file in the recorder's office of the county wherein the water-right is situated a declaration in writing, except notice be given of record setting forth the same facts required in the notice provided for in section 6 of this act. The declaration shall be verified as before required in cases of notice of appropriation of water: *Provided*, That a failure to comply with the requirements of this section may in no wise work a forfeiture of such heretofore acquired rights, nor prevent any such claimant from establishing such rights in the courts.

SEC. 10. The record provided for in the preceding sections, when duly made, shall be taken and received in all the courts as *prima facie* evidence of the statements therein contained.

SEC. 11. In any suit hereafter commenced for the protection of rights acquired to water, the plaintiff may make any or all persons who have diverted water from the same stream or source parties to such action, and the court may in one decree settle the relative priorities and rights of the parties to such suit. When damages are claimed for the wrongful diversion of water, the same may be assessed and apportioned by the jury in their verdicts, and judgment may be entered for or against one or more of several defendants, and may determine the ultimate rights of parties between themselves.

SEC. 12. In any action concerning joint water-right, or joint rights in water-ditches, unless partition of the same is asked by parties to the action, the court shall hear and determine such controversy as if the same were several as well as joint.

SEC. 13. The recorder of each county must keep a well-bound book, in which he must record the notices and declarations provided for in this act, and he shall be entitled to have and receive the same fees as are now or hereafter may be allowed by law for recording instruments entitled to be recorded.

SEC. 14. The measurement of water appropriated shall be conducted in the following manner: A box or flume shall be constructed, with a head-gate placed so as to leave an opening of 6 inches between the bottom of the box or flume and lower edge of the head-gate, with a slide to enter at one side of and of sufficient width to close the opening left by the head-gate, by means of which the dimensions of the opening are to be adjusted. The box or flume shall be placed level, and so arranged that the stream in passing through the aperture is not obstructed by backwater or an eddy below the gate; but before entering the opening to be measured the stream shall be brought to an eddy, and shall stand 3 inches on the head-gate and above the top of the opening. The number of square inches contained in the opening shall be the measure of inches of water.

IDAHO.

The general laws of Idaho, 1881, in an act regulating rights to the use of water for mining, agricultural, manufacturing, and other purposes, contain provisions, the substance of which is as follows:

SECTION 1. The right to the use of water flowing in a river, creek, cañon, ravine, or other stream, may be acquired by appropriation, and as between appropriations priority in time shall secure the priority of right.

SEC. 2. The appropriation must be in good faith, for some useful and beneficial purpose, and when once perfected, may be converted or changed to any other beneficial use than that originally designated or for which it may have been employed.

SEC. 3. The appropriator, or his or their successors in interest, may change the place of diversion, if the rights acquired by others are not interfered with, and no injury to others results therefrom, and may also extend any ditch, canal, flume, pipe, or other conduit to points or places beyond such as may have accrued prior to such extension.

SEC. 4. A person, company or corporation, desiring to appropriate water must post a notice in writing in a conspicuous place, at the point of intended diversion, stating

First, the quantity of water intended to be claimed and diverted, giving the number of inches, measured under a 4-inch pressure, and accurately describing the point of its diversion.

Second, the purpose for which the same is claimed or intended to be used, and the point or place of such intended use.

Third, the means which are designed to be employed for diverting and conducting the waters, and the size or dimensions of the ditch, canal, pipe, flume or other conduit. A copy of the notice, within the time allowed for a mining claim, must be furnished to the county officer for record.

SEC. 5. Within sixty days after the notice is posted the claimant or his or their successors in interest, must commence the making, digging or constructing of the ditch, canal, flume, or other conduit, the work for the complete diversion and conducting of the water shall be prosecuted diligently and without unnecessary interruption: *Provided*, That when the work cannot be carried on by reason of unavoidable natural causes, such as the state of the weather or action of the elements, this section shall not be applicable.

SEC. 6. By "complete diversion" is meant the conducting of the water claimed to the place of intended use, or to such other place as may have been adopted, and an actual beneficial use made.

SEC. 7. By compliance with the above conditions and requirements the appropriation is perfected, and the right to the use of the waters claimed, which the ditch, canal, flume or other conduit is capable of conducting, is declared to relate back to the time of the posting of notice of claim: *Provided*, That nothing contained in this section shall be so construed as to render any person or party liable to damages or to make compensation to any appropriator for any waters used prior to the time of a "complete diversion."

SEC. 8. All ditches, canals, and other works heretofore made, constructed, or provided, and by the means of which the waters of any stream have been diverted and applied to any beneficial use, shall be taken to have secured the right to the waters claimed to the extent of the quantity which the works are capable of conducting, and not exceeding the quantity claimed, without regard to or in compliance with the requirements of this act.

SEC. 9. In case where any person, company, or corporation have heretofore made claim to divert the waters of any stream and the same has not been forfeited or abandoned, and have not cut, excavated, made, or constructed the necessary ditch, canal, flume, or other conduit to carry such waters and apply the same to a beneficial use, such claimant must, within four months from and after the date of the approval of this act, commence work in pursuance with the requirements, and carry the same to completion, or at the expiration of the time or upon failure to prosecute the work in the manner required, the claim shall cease to be of any validity as to the foundation of a right to the waters of any stream.

SEC. 10. All persons, companies, and corporations owning or claiming any lands situated on the banks or in the vicinity of any stream, shall be entitled to the use of the waters for the purpose of irrigating the land so held or claimed.

SEC. 11. Whenever any such owner or claimant to land has not sufficient length of frontage on a stream to afford the requisite fall for a ditch, canal, or other conduit in his own premises, or where the land proposed to be irrigated is back from the banks of the stream and convenient facilities for watering the land cannot be had, the owner or claimant shall be entitled to the right of way through the lands of others for the purposes of irrigation: *Provided*, That in making, constructing, keeping up, and maintenance of the ditch, canal, or conduit through the lands of others, the person, company, or corporation and those succeeding to the interests of the same shall keep the ditch, canal, or other conduit in good repair, and shall also be liable to the owners or claimants of the lands crossed for all damages which may be occasioned by an overflow or result from any neglect or accident (unless the same be unavoidable).

SEC. 12. In case of the refusal of the owners or claimants of any lands through which such ditch, canal, or other works are proposed to be made or constructed, to allow a passage, the persons, company, or corporation desiring the right of way may present a petition to the county commissioners describing the lands to be crossed, the size of the ditch, canal, or works, the quantity of land required, giving the names of the owners or parties interested, and asking for appointment of three appraisers to ascertain the compensation to be made. When the petition is filed the county commissioners shall give notice, either by newspaper publication or notices in three public places, one the county seat, that the appraisers will be appointed, unless good cause be shown by the parties adversely interested why the petition should be denied. The notice must be published or posted not less than thirty days prior to the hearing, and the expense defrayed by the petitioners.

SEC. 13. The appraisers shall impartially hear the proofs and allegations offered by the respective parties, and, after viewing the lands and premises, shall ascertain and certify the compensation proper to be paid for the right of way to the parties owning or interested in the lands to be crossed and the damages, if any, after making allowance for real or direct benefits which the owner or party interested may desire from the making of a ditch, canal, or other works. They, or a majority of them, shall subscribe the certificate, and it shall be recorded in the county recorder's office, and upon the payment or tender of the compensation and damages, if any, or the deposit of such amount in the county treasury to the credit of the party or parties interested, the persons, company, or corporations shall have the right of way for the proposed ditch, canal, or other works.

SEC. 14. All persons, companies, or corporations owning or having the possessory title or right to lands adjacent to any stream, shall have the right to place in the channel of or upon the banks or margin of the same rams or other machines for the purpose of raising the water to a level above the banks of such heights as may be requisite for its flow to and upon the lands, and the right of way over and across the lands of others for conducting the waters may be acquired in the manner heretofore mentioned.

SEC. 15. Where the owners of any spring or the appropriators of any stream may desire to conduct the waters to any lands for irrigation, or to any city or town for the use of the inhabitants, or to any factory, or to any distant place, with the intent to apply the same to a beneficial use, and where to accomplish the object it may be necessary to cross with ditches, flumes, or other conduit the lands owned and occupied by others than the owners or appropriators of the spring or stream, the right of way over and across the lands of others may be acquired in the manner prescribed in the preceding section.

SEC. 16. The owners or constructors of ditches, canals, works, or other aqueducts, and their successors in interest, using and employing the same to convey the waters of any stream or spring, whether the ditches, canals, works, or aqueducts be upon the lands owned or claimed by them, or upon other lands, shall keep and maintain the same, and the embankments, flumes, or other conduit by which the waters are or may be conducted, in good repair and condition, so as not to damage or in any way injure the property or premises of others.

SEC. 17. Nothing in this act shall be so construed as to interfere with or impair the rights to water appropriated and acquired prior to the passage of this act, but this reservation in behalf of existing rights shall not exempt such appropriators from liability as heretofore provided.

SEC. 18. In case the volume of water in any stream shall not be sufficient to supply continually the wants for irrigating purposes of the owners or proprietors of land in any district or neighborhood in which customs exist for distributing the waters amongst such owners or proprietors, the water diverted shall, in such case, be held to be a common right in those accustomed to a participation in the use and enjoyment of the distribution, and such custom shall be upheld in all courts as conferring the common right in the same: *Provided*, That this section shall not be construed to affect any prior vested right.

SEC. 19. In case any person, company, or corporation shall have constructed a ditch for the purpose of directing the water of any river, creek, cañon, ravine, or spring, for the purpose of selling the water for irrigating purposes, the owners or cultivators of land along the line of, and covered by, the ditch or canal shall be entitled to, and have the right to, the use of water for the purpose of irrigating in the following order: First, all persons through whose land the ditch or canal runs shall be entitled to the use of the water in the order of their location; second, after those through whose land the ditch or canal runs, those upon either side of the line of the ditch or canal shall be entitled to the use of the water; those equally distant from the line shall be entitled to priority in the order of their location along the line: *Provided always*, That the owners or cultivators of such lands shall pay the usual and customary rates for the use of the water, and whenever any ditch or canal has been constructed for the purpose of conveying water and selling the same for irrigating purposes it shall be unlawful for the owner or owners to change the line so as to prevent or interfere with the use of water by any one who, prior to the proposed change, had used water for irrigating purposes. And it is the duty of the owner or owners to keep the same in good repair, and to cause the water to flow through to the extent of its capacity, provided so much may be needed during the entire time that water may be necessary for irrigating purposes: *And provided further*, That the river, creek, cañon, ravine, or spring from which the water is taken furnishes an amount of water sufficient for such purpose, subject to the appropriation of the owner or owners of the ditch or canal. For a failure to cause the water to flow, the owner or owners or lessees of any such ditch shall be personally liable to any one for any damage resulting from the failure; and in addition to personal liability the damages shall be a lien upon the ditch or canal, which shall continue in force until the damages are paid. No person entitled to the use of water from any such ditch or canal shall, under any circumstances, use more water than good husbandry shall require for the crop or crops that he shall cultivate; and any person using an excess of water shall be liable to the owner or owners for the value of the excess, and, in addition, shall be liable to all damages sustained by any other person who would have been entitled to the use of the excess of water.

The General Laws of 1881, in an act regulating the distribution of water for purposes of irrigation, also contain provisions the substance of which is as follows:

SECTION 1. The inhabitants of any vicinity or neighborhood who use the waters of any ditch, stream, or spring for the purpose of irrigation, or have or claim a common right to the same for such purposes, shall constitute a water district, and a majority of the inhabitants having the common right may annually, on the fourth Monday of March, elect a water-master, whose duties shall be to superintend the distribution of the waters among those having the common right. The water-master shall file a bond, faithfully to perform his duties, in the sum of $500, with two sufficient sureties, in the county recorder's office of the county wherein the district is situated, and he shall employ one or more deputies, as authorized by the inhabitants of his district, and they shall receive such compensation as the inhabitants agree upon.

SEC. 2. The owner or owners of any ditch for the distribution and sale of water for the purposes of irrigation shall employ a water-master for the distribution of the water of the ditch to the persons purchasing the same for such purposes, and no account or demand for the use of the water during any time the water-master is not so employed shall be valid or collectable.

SEC. 3. The water-master and his deputies shall regulate the distribution of water among the several ditches of his district and among the several inhabitants entitled and accustomed to the use according to their respective rights and necessities, and when the quantity of water is not sufficient to afford a supply to those entitled to it, the water-master and his deputies shall regulate the quantity to be used by each person and the time at and during which each person may use the same: *Provided*, That nothing in this act shall be so construed as to interfere with the individual right of companies or corporations, or in any manner interfere with the rights of individuals, companies, or corporations, to the use and control of water which is or may be their private property.

SEC. 4. Where a ditch is common property, or there is a common right to the use of the water of a ditch without payment, and any labor or materials are necessary for the repair or cleaning of the ditch, or any gate or flume on or belonging to it, the water-master may make a fair *pro rata* assessment of labor or materials against the inhabitants of the district claiming the use of such water according to the benefits received by each, and if any person so assessed shall neglect or refuse, for the period of ten days after notice, to furnish his just proportion of labor or materials, he shall forfeit all rights to the use of the water from the ditch for the year in which he shall make such defaults.

SEC. 5. The water-master shall see that there are provided the necessary and proper head-gates and dams, and that the water is turned and runs into the ditches of his district at the proper season of the year; and he may require all persons receiving water to construct proper gates at the points at which they take water from any ditch, dam, or reservoir; and he shall have such control of the location of ditches and gates as may be necessary to secure the most equitable distribution of the water among those entitled to its use.

SEC. 6. Any person who shall, without the consent of the water-master of the district, divert any water from the ditch or channel where it was placed or caused or left to run by the water-master and his deputies, or who shall shut or open any ditch, gate, or dam with intent so to divert any water, and thereby deprive any person of the use of the same during any part of the time he is entitled to it, or who shall cut any ditch or the banks thereof, or break or destroy any gate or flume, shall be fined not less than five nor more than twenty dollars, and shall be liable to any person injured in three times the actual damage sustained.

WYOMING.

The irrigation laws of Wyoming, 1884, in chapter II, on rights to water of streams and construction of irrigating ditches, contain in substance the following provisions:

SECTION 1. All persons who claim, own, or hold a possessory right, or title to any land or parcel of land, when those claims are on the bank, margin, or in the neighborhood of any stream of water, creek, or river, shall be entitled to the use of the water for the purpose of irrigation, and making the claim available, to the full extent of the soil, for agricultural purposes.

SEC. 2. When any person owning claims in such locality has not sufficient length of area exposed to the streams to obtain a sufficient fall of water to irrigate his land, or his farm or land used for agricultural purposes is too far removed from the stream, and he has no water facilities on those lands, he shall be entitled to a right of way through the farms or tracts of land which lie above and below him on the stream, for the purposes hereinbefore stated: *Provided*, That in the construction, keeping up and using of any ditch through the land of another person the person or persons constructing or using the ditch, or whose duty it shall be to keep the same in repair, shall be liable to the person owning or claiming the land for all damages.

SEC. 3. Such right of way shall extend only to a ditch, dike, or cutting sufficient for the purposes required.

SEC. 4. In case the volume of water in the stream, creek, or river shall not be sufficient to supply the continual wants of the entire country through which it passes, then the county commissioners shall appoint three commissioners, as hereinafter provided, who shall apportion in a just and equitable proportion a certain amount of water upon certain and alternate weekly days to different localities, and with due regard to the legal rights of all.

SEC. 5. Upon the refusal of the owners of tracts of land or lands through which the ditch is proposed to run to allow its passage through their property, the person desiring to open such a ditch may present to the commissioners of the county wherein the lands are located a petition describing the lands required, giving the name or names of the owner or other persons interested, and asking for the appointment of appraisers to ascertain the compensation to be made to the owner or persons interested. The commissioners shall give thirty days notice prior to the appointment of appraisers by newspaper publication, or posting three or more notices in three different places in the county.

SEC. 6. The appraisers shall impartially hear the proofs and allegations of the parties, and any two of them, after reviewing the premises, shall ascertain and certify the proper compensation to be made for the lands taken or affected as well as the damages, making allowances for such real benefits or advantages as the owner or parties interested may derive from the construction of the ditch or flume. They or a majority of them shall subscribe a certificate of their ascertainments and assessment, which shall be recorded in the county clerk's office, and upon payment of the compensation (if any) the said person or persons shall have the right of way to construct the ditch or flume.

SEC. 7. All persons on the margin or bank or in the neighborhood or precinct of any stream shall have the right and power to place upon the bank of the stream a wheel or other machine, for the purpose of raising water to the level required for the purpose of irrigation, and the right of way shall not be refused by the owner of any tract of land upon which it is required, subject, of course, to the like regulations as required for ditches.

SEC. 8. The owner or owners of any ditch for irrigation or other purposes shall carefully maintain the embankments, so that the waters of the ditch may not flood or damage the premises of others.

SEC. 9. Nothing in this chapter shall be so construed as to impair the prior vested rights of any mill or ditch owner or other person to use the waters of any such water-course.

SEC. 10. The commissioners hereinbefore provided for shall not be appointed until at least ten days previous notice shall have been given to the parties in interest, by posting notices of the time and place, when and where the appointments will be made, in at least three public places within the region watered by the stream, creek, or river.

SEC. 11. Any ditch company constructing a ditch, or any individual having ditches for irrigation or for other purposes, whenever the same be taken across any public highway or public traveled road, shall put a good substantial bridge (not less than 14 feet in width) over such water-course where it crosses the road.

SEC. 12. When any such ditch or water-course shall be constructed across any public traveled road and not bridged within three days thereafter, the county commissioners shall put a bridge over the ditch or water-course, of the dimensions specified, and call upon the owner or owners to pay the expense of construction, and if payment be refused a civil action may be maintained for recovery of the same together with all costs.

SEC. 13. Upon the refusal of the owner or owners of land or lands through which any person or persons are desirous of constructing any irrigation ditch or ditches, it shall be lawful for the parties interested to settle the matter by the appointment of a board of arbitration consisting of three men, as hereinafter provided.

SEC. 14. The creation of the board of arbitration shall be as follows: The person or persons desiring the construction of such ditch or ditches, and the owner or owners of the land or lands through which the ditch or ditches are contemplated, shall each choose one disinterested resident property holder of the county, and the two chosen shall designate a third, and after having the proofs and allegations of the parties concerned, two of the board of arbitration shall make such assessment of damages as they deem just and right, taking into consideration the benefit (if any) that may accrue to the owner or owners of the land or lands.

SEC. 15. Should the verdict or assessment be unsatisfactory to either or both parties interested, an appeal may be taken in writing within ten days from the rendering of the verdict to the commissioners of the county where the contestants reside, in which case the party taking the appeal shall give bonds for all costs. The case shall then stand as though no action had been taken in the matter, and the parties may proceed as if the matter had been taken before the county commissioners in the first instance.

SEC. 16. In case no appeal be taken by either of the parties interested, then the finding of the board of arbitration shall be binding and final: *Provided*, That the sum of money agreed upon by the board has been tendered or a deed for such right of way executed and delivered or tendered, by the party or parties over whose land the right of way is sought.

SEC. 17. Willful or malicious damages or destruction of property of another by any person shall be punished by a fine not exceeding one hundred dollars or imprisonment in the county jail not exceeding six months or both.

SEC. 18. At any time hereafter any three or more persons who may desire to form a company for the purpose of carrying on any kind of manufacturing, mining, chemical, merchandising, or mechanical business, constructing wagon-roads, railroads, or telegraph-lines, digging ditches, building flumes, mining-tunnels, or carrying on any branch of business designed to aid in advancing the industrial or productive interests of the country, may make, sign and acknowledge before some officer competent to take acknowledgments of deeds, duplicate certificates in writing, in which shall be stated the corporate name of the company and the object for which it shall be formed, the amount of capital stock, the term of its existence, not to exceed fifty years, the number of shares, the number and names of the trustees, who shall manage the concerns the first year, and the name of the town and county in which the operations shall be carried on. They shall file one of the certificates in the county clerk's office of each county where the business is to be carried on, and one in the office of the secretary of the Territory. The county clerk shall record the certificate: *Provided*, That any three or more persons who desire to form a company the object of which shall be to aid the industrial or productive interests of the country, without any purpose of direct gains to itself, then and in such case the company shall not have a capital stock, and the certificate shall contain no statements appertaining to stock, but the company shall state and show in such certificate that it is not organized for direct gain, and has no capital stock; and the members and officers of such company shall be fixed and provided for by the by-laws of the company.

SEC. 19. All the companies heretofore organized may execute and file with the secretary and county clerk a supplemental certificate, and on the filing of such certificate the company shall become and shall thereafter be a legal corporation.

SEC. 20. Whenever any three or more persons form a company for the purpose of constructing a ditch or ditches for conveying water to any mines, mills, or lands to be used for mining, milling, or irrigation, they shall in their certificate, in addition to matters heretofore required, specify as follows: The streams or stream from which the water is to be taken; the point or place at or near which the water is to be diverted; the line of the ditch or ditches, as near as may be, and the use to which the water is intended to be applied.

SEC. 21. Any ditch company shall have the right of way over the lines named in the certificate, and shall also have the right to run the water of the stream or streams through their ditch or ditches: *Provided*, That the line proposed shall not interfere with any other ditch whose rights are prior, nor shall the water of any stream be diverted from its original channel to the detriment of any miners, millmen, or others along the line of the stream who have a priority of right; and there shall be at all times left sufficient water for the use of miners and agriculturists who may have a prior right.

SEC. 22. Any company constructing a ditch or ditches shall furnish water to the class of persons using water, in the way named in the certificate, whether miners, millmen, or farmers, whenever they shall have water in their ditch or ditches unsold, and shall at all times give the preference to such class of persons, the rates at which water shall be furnished to be fixed by the county commissioner or the tribunal transacting county business, as soon as the ditch or ditches shall be completed and prepared to furnish water.

SEC. 23. Every ditch company shall be required to keep the banks of their ditch or ditches in good condition, so that the water shall not be allowed to escape to the injury of any mining claim, road, ditch, or other property located and held prior to the location of such ditches; and whenever it is necessary to carry any ditch over or across or above any lode or mining claim, the company shall, if necessary to keep the water of the ditch out or from any claim, flume the ditch so far as necessary to protect such claims or property: *Provided*, That in all cases where the ditch has priority of right by location the owners of such claim or property shall be compelled to protect themselves from any damage that might be created by said ditch, and the owner of such claim shall be liable for any damages resulting to the ditch by reason of the works or operations performed on such claim or property.

SEC. 24. The last four preceding sections shall apply to all ditch companies already formed and incorporated.

SEC. 25. When any company shall be organized for the purpose of constructing a flume, their certificate, in addition to the matters heretofore required, shall specify as follows: The place of beginning, termini, and the route as near as may be, and purpose for which the flume is intended, and when organized the company shall have the right of way over the line proposed in the certificate: *Provided*, That it does not conflict with the right of any former fluming, ditching, or other company.

SEC. 26. Whenever any road, railroad, ditch, telegraph, or fluming company, organized or to be organized, shall not have acquired, by gift or purchase, the right of way for the construction and maintenance of the same, the corporation may present a petition to the district judge praying for the appointment of appraisers to ascertain the compensation to be made to the owner and persons interested. The judge, having evidence that the notice of intended application has been given at least ten days previously to the owners, either by newspaper publication or three or more notices posted in some public places in the county, shall appoint three disinterested appraisers. These appraisers shall hear the proof and allegations of the parties, and any two of them shall, after reviewing the premises, ascertain and certify the compensation to be made as well as the damages accruing to the parties interested, making deduction or allowance for such real benefits or advantages as the owners may derive from the construction of the road, railroad, ditch, telegraph, or flume. They shall file with the register of deeds of the county a certificate of their ascertainment and assessment. The judge, upon the certificate and proof that the compensation has been paid or deposited to the credit of the parties entitled to it, shall make a rule describing the land, real estate, or claims, the ascertainment of compensation, and each payment or deposit, and a certified copy shall be recorded as if it were a deed of conveyance from the owner and parties interested to the corporation. Upon the entry of the rule the corporation shall, during its continuance, have the exclusive right, title, or possession of all lands, real estate, or claims required to be taken, and shall be discharged from all claims for any damage. If at any time the title acquired be deemed defective, the corporation may proceed to perfect it, making payment in the manner hereinafter provided. The judge may authorize the corporation to take possession (if not already in possession) of the premises, and to use the same during the pending and until the final conclusion of the proceedings, and may stay all actions on account thereof: *Provided*, That the corporation shall pay a sufficient sum into court, or give approved security to pay the compensation when ascertained, and in every case where possession shall be so authorized the owners shall conduct the proceedings to a conclusion, if the same be delayed by the company.

SEC. 27. Any company formed for the purpose of constructing any road, ditch, flume, bridge, ferry, or telegraph-line shall within six months from the date of their certificate, commence work, and shall prosecute it with diligence until completed, and the time of completion of any such road, bridge, ferry, or telegraph-line shall not be extended beyond a period of two years, of any ditch five years, and of any flume four years, from the time the work was commenced. Any company failing to commence work within six months from the date of certificate, or failing to complete it within the time stated, shall forfeit its claim to that portion of the route upon which it has failed to do the specified work: *Provided*, That this section shall not apply to any ditch or flume for mining purposes constructed through any ground owned by the corporation.

SEC. 28. No dam or boom shall hereafter be constructed or permitted on any river of sufficient size for floating or drawing logs, timber, or lumber, and which may be used for that purpose, unless the dam or boom have a sluice-way lock or other fixture sufficient connected with it, so arranged as to permit logs, cross-ties, wood, telegraph-poles, timber, and lumber to pass through, around, or over the dam or boom, without unreasonable delay or hindrance.

SEC. 29. Any boom or weir now in or over any river that is so constructed as to prevent the free passage of logs or lumber is declared a nuisance, and shall be abated, unless a suitable sluice-way lock or passage be made within thirty days after written notice given by any person interested, and any person or persons so owning, holding or occupying said boom or weir shall be liable to pay $5 for every day the same shall remain in or over the river, after having had thirty days' notice to remove the nuisance (which sum may be recovered before any justice of the peace having jurisdiction, and the amount shall be paid into the county treasury for the support of the common schools) and such person or persons shall furthermore be liable for any damages sustained by individuals by reason of the nuisance.

SEC. 30. Any person or persons, corporation or corporations, using water through any ditch or canal now constructed or which may be hereafter constructed, or using water through any natural ditch or slough from any creek or river which is of sufficient size for floating or driving logs, lumber, timber, railroad-ties, poles, rails, posts, or firewood, and which may be used for that purpose, shall erect and maintain in good order a head-gate across the ditch, canal or slough at or near the bank of the creek or river where such ditch, canal, or slough opens out, sufficient to prevent logs, lumber, timber, railroad-ties, poles, rails, posts, or firewood from floating into any such ditch, canal, or slough: *Provided*, That the foregoing shall not apply to natural sloughs where the water runs through without being dammed or flumed.

SEC. 31. If any person or persons, corporation or corporations, shall fail or neglect to erect and maintain a sufficient head-gate as required, they shall have no recourse for damages sustained by them through such failure and neglect.

SEC. 32. All creeks and rivers of sufficient size for floating or driving logs, timber or lumber, and which may be used for that purpose, are declared public highways, so far as to prevent obstruction to the free passage of logs, cross-ties, wood, telegraph-poles, timber, or lumber down such streams.

NEW MEXICO.

The treaty of peace between the United States and Mexico in 1848 contains the following provisions in articles VIII and IX:

ART. VIII. Mexicans now established in territories previously belonging to Mexico, and which remain for the future within the limits of the United States as defined by the present treaty, shall be free to continue where they now reside, or to remove at any time to the Mexican Republic, retaining the property which they possess in the said territories, or disposing thereof and removing the proceeds wherever they please, without being subjected on this account, to any contribution, tax, or charge whatever.

Those who shall prefer to remain in the said territories may either retain the title and rights of Mexican citizens, or acquire those of citizens of the United States; but they shall be under the obligations to make their election within one year from the date of the exchange of ratifications of this treaty, and those who shall remain in the said territories after the expiration of that year without having declared their intentions to retain the character of Mexicans shall be considered to have elected to become citizens of the United States. In the said territories property of every kind now belonging to Mexicans not established there shall be inviolably respected. The present owners, the heirs of these, and all Mexicans who may hereafter acquire said property by contract shall enjoy with respect to it guarantees equally ample as if the same belonged to citizens of the United States.

ART. IX. Mexicans who in the territories aforesaid shall not preserve the character of citizens of the Mexican Republic conformably with what is stipulated in the preceding article shall be incorporated into the union of the United States and be admitted at the proper time (to be judged of by the Congress of the United States) to the enjoyment of all the rights of citizens of the United States according to the principles of the Constitution, and in the mean time shall be maintained and protected in the free enjoyment of their liberty and property, and secured in the free exercise of their religion, without restriction.

The Gadsden treaty between the United States and Mexico in 1853 contains the following provisions in Article V:

All the provisions of the eighth and ninth, sixteenth and seventeenth articles of the treaty of Guadalupe Hidalgo shall apply to the territory ceded by the Mexican Republic in the first article of the present treaty, and to all the rights of persons and property, both civil and ecclesiastical, within the same, as fully and as effectually as if the said articles were herein again recited and set forth.

The Kearney code of laws, 1846, contains in section 1 the following provisions relative to water-courses, stock-marks, &c.:

The laws heretofore in force concerning water-courses, stock-marks and brands, horses, inclosures, commons, and arbitrations shall continue in force, except so much of said laws as require the ayuntamientos of the different villages to regulate these subjects. The dutities and powers of such ayuntamientos are transferred to and enjoined upon alcaldes and prefects of the several countries.

The general statutes of New Mexico, 1884, contain in substance the following provisions in Title I, Chapters I and II, relative to acequias:

SECTION 1. No inhabitant shall have the right to construct any building to the impediment of the irrigation of lands or fields, such as mills or any other property, that may obstruct the course of the water, as the irrigation of the fields should be paramount to all other uses of the water.

SEC. 2. All by-paths or foot-paths are prohibited across the fields under penalty of fine or imprisonment.

SEC. 3. It being impracticable or absolutely impossible for the fields to be fenced in, all animals shall be kept under a shepherd, so that no injury may result to the fields, and in case any damage should result it shall be paid by the persons causing it.

SEC. 4. In case a community of people desire to construct a ditch or acequia, and the constructors are the owners of all the land upon which the ditch or acequia is constructed, no one shall be bound to pay for the land, as all persons interested in the construction are to be benefited by it.

SEC. 5. The course of ditches or acequias already established shall not be disturbed.

SEC. 6. All rivers and streams of water heretofore known as public ditches or acequias are hereby established and declared to be public ditches or acequias.

SEC. 7. From and after the publication of this act it shall be the duty of the several justices of the peace to call together in their respective precincts, whenever it may be deemed convenient, all the owners of ditches or acequias, as well as the proprietors of lands irrigated by any public ditch or acequia, for the purpose of electing one or more overseers for the ditches or acequias for the same year.

SEC. 8. All fines and forfeitures recovered for the use and benefit of any public ditch or acequia shall be applied by the overseer to the improvements, excavation and to bridges for the same, wherever it is crossed by any public road and bridges may be necessary.

SEC. 9. In all cases of conviction under this act an appeal may be granted to the district court, which appeal shall be taken and conducted as all other appeals from the decisions of justices of the peace.

SEC. 10. The regulations of ditches or acequias which have been worked, shall remain as they were made, and have remained up to this day.

SEC. 11. All plants of any description growing on the banks of the ditches or acequias, shall belong to the owners of the land through which the ditches or acequias run.

SEC. 12. If any person or persons intentionally make lagoons of water, whether on their own or other land, after the gathering of the crops, from which lagoons damage results to houses, common or private grounds or public roads, the person so offending shall, on conviction, be fined in any sum not less than five nor more than ten dollars.

SEC. 13. Any person convicted of having committed injuries heretofore mentioned, shall pay to the party injured the damages assessed by three persons appointed for that purpose by the justice.

SEC. 14. All fines arising from the provisions of this act shall be applied to the repairs herein mentioned, and in case of not being so expended, they shall go into the treasury of the county wherein they were collected.

SEC. 15. All acequias, public or private, when completed, shall be the property of the persons who may have completed them, and no person or persons who may desire the use of the waters of them shall be allowed to do so without the consent of a majority of the owners, and upon payment of a share proportionate to the primary cost of the acequia or ditch to the amount of the land proposed to be irrigated, or the quantity of water proposed to be used: *Provided*, that the provisions of this section shall not apply to any acequias or ditches, public or private, that may pass from the limits of any one county to within the lines of any other.

SEC. 16. Where any acequia or ditch, public or private, passes from within the limits of any one county to within the lines of any other, such acequia or ditch within the proper precincts of the respective counties, shall be under the exclusive control and management of the officers of such precincts and counties.

SEC. 17. All the inhabitants shall have the right to construct either private or common acequias, and to take the water for them from wherever they can, with the distinct understanding to pay the owner through whose lands the acequias have to pass a just compensation for the land used.

SEC. 18. If the owner or owners of lands where a new ditch for an acequia is to be made should ask an exorbitant price as a compensation, which shall not be satisfactory to the owner or owners of the acequia, the probate judge of the county shall appoint three honest, skillful men to make an appraisement and fix the compensation, which once done shall be executed and without appeal.

SEC. 19. When any public ditch or part thereof shall be destroyed by rain, or in any other manner, and it shall be absolutely impossible to reconstruct it where it ran before it was destroyed, the major-domo of the ditch, with the consent, should they deem it necessary, of a majority of those having a common interest therein, may cut through the lands of any person or persons, by first obtaining their consent, the community interested in the ditch offering to pay a compensation to be agreed upon between them and the owner or owners of the lands through which the ditch is to be opened.

Sec. 20. If the owner or owners who shall be solicited to permit the opening of a new ditch through their lands should refuse or decline to accept the compensation offered, or should ask a compensation which the interested parties consider exorbitant, the major-domo shall lay the case before the justice of the peace of the precinct, and he shall appoint three men, experts, to establish a just compensation to be paid to the owner or owners through whose lands the ditch is to pass.

Sec. 21. Whenever three experts shall be appointed as appraisers, they shall file in the office of the justice of the peace an oath impartially to discharge their duties, and shall proceed to the place where the land or lands are situated, and, before appraising, shall ascertain whether or not the ditch is destroyed, and whether the labor or cost required to rebuild it would be so great as to render its reconstruction impossible; and if they think the injury done may be repaired they will so report to the justice of the peace, and the land solicited for the purpose of opening the new ditch shall in no manner be touched; but if they should think a part of the ditch irreparably destroyed, they shall then examine the land or lands over which the new ditch should be opened and the place where it should properly run.

Sec. 22. Whenever any land or lands of any person or persons are appraised the appraisers shall file a report in the office of the justice of the peace who appointed them, giving the name of the person whose land was appraised and the sum to be paid him by the parties interested in the public ditch for which the right of way through the land is solicited; they shall also state, in the most distinct manner, the place and point where the opening for the ditch is to be made, and the direction which the ditch is to take through such land.

Sec. 23. The parties interested shall possess the right of property in the land or lands assigned to them, and in case of legal resistance being made, they may in an action of forcible entry and detainer, as provided by law, compel the person or persons who interpose such resistance to desist therefrom; but the parties interested shall first pay the appraised value of the land or lands: *Provided*, that the appraisers shall be impartial persons.

Sec. 24. In each precinct where public necessity requires it, an election shall, on the third Monday of February, 1880, be held, as hereinafter provided, for directors of such of the acequias as irrigate different places.

Sec. 25. The manner of conducting the election, and the number of overseers, shall be regulated by the justice of the peace, and the only persons entitled to vote at the elections, shall be the owners or renters of lands irrigated by the ditches or acequias.

Sec. 26. The overseers shall superintend the repairs and excavations on the ditches or acequias; apportion the number of laborers furnished by the proprietors; regulate them according to the quantity of land to be irrigated by each one; distribute and apportion the water in the proportion to which each one is entitled, according to the land cultivated by him, taking into consideration the nature of the seed, crops, and plants cultivated.

Sec. 27. If any overseer of any public ditch or acequia shall willfully neglect or refuse to fulfill his duties, or conduct himself with impropriety or injustice, or take any bribe, in money, property, or otherwise, he shall be fined for each of such offenses, in a sum not exceeding $90, to be recovered before any justice of the peace in the county, one-half the sum to be paid to the county, and the other half to the person bringing suit; and on a second conviction may be removed from his office, on petition of two-thirds of the proprietors of the land irrigated.

Sec. 28. In all cases of removal, the justice of the peace shall order a new election to fill the vacancy occasioned by it.

Sec. 29. The pay and other perquisites of the overseers shall be determined by a majority of the owners of the land irrigated by the ditch or acequia.

Sec. 30. In acequias of extended irrigation, and where the lands which they irrigate are unequal, and some persons have at once several sections and parts in other sections, there shall be elected a chief major-domo, an assistant major-domo, and three acequia commissioners. The duties of the commissioners shall be to regulate the number of laborers for the respective acequias for which they have been elected, that shall be furnished by each owner or tenant of irrigable lands to be irrigated. Should it be necessary, or should any three persons, owners or tenants require it, the commissioners shall measure the lands in order to better apportion the number of laborers that each owner or tenant shall supply for the cleaning up of the acequias, and for any subsequent work which public necessity may demand during the year, the care of which is charged to the major-domos and assistant major-domos, the chief major-domo being always the superior officer; and he, with his assistant, shall take care that the acequias shall be kept running in all their vigor from the time the water is first let in after cleaning until the crops no longer require it.

SEC. 31. Whenever a list has been made by the acequia commissioners, as provided in the foregoing section, at any of the acequias, or by any major-domo and his assistant, where commissioners are not elected, another list shall be made and delivered to the justice of the peace, who shall record it for the reference of all interested parties and in order that the work may be so ordered.

SEC. 32. The chief majors-domo of all the acequias shall be the receivers and disbursers of all the fines resulting from their respective acequias, and on the tenth of October in each year they shall give an account to the justices of the peace of their precincts of the fines received and the manner in which they have disbursed any part of them.

SEC. 33. Should the commissioners be charged with the duty of measuring the lands, they shall be paid at the rate of two dollars per diem during the time they may be so occupied; which sum shall be paid from the respective funds belonging to the acequias.

SEC. 34. In the elections every owner or tenant of irrigable lands, irrigated by any of the accquias, shall be entitled to vote and be voted for. The persons receiving the greatest number of votes shall be declared elected to their respective offices; and shall receive a certificate of the same from their respective justices of the peace. All such elections shall be held from and after the year eighteen hundred and eighty-one, on the first Monday of January in each year.

SEC. 35. All persons interested in a common ditch or acequia, be they owners or lessees, shall labor thereon in proportion to their land.

SEC. 36. All owners of tillable lands shall labor on public ditches or acequias, whether they cultivate the land or not.

SEC. 37. Each proprietor shall furnish the number of laborers required by the overseer, at the time and place he may designate, and for the time he may deem necessary.

SEC. 38. If a proprietor of land irrigated by any such ditch or acequia, shall neglect or refuse to furnish the number of laborers required by the overseer, after having been legally notified, he shall be fined for each offense in a sum not exceeding ten dollars for the benefit of the ditch or acequia, and the overseer shall be a competent witness to prove the offense.

SEC. 39. If any person shall in any manner obstruct, interfere with, or disturb any of the ditches or acequias, or use the water therefrom without the consent of the overseer, during the time of cultivation, he shall pay for each offense a sum not exceeding ten dollars and all damages that may have accrued to the injured parties, and if the person or persons are unable to pay the fine and damages, they shall be sentenced to fifteen days' labor on public works.

SEC. 40. All overseers of ditches shall see that the water currents run so that no injury may result to the proprietors of lands or tenements or to the public convenience; and in case danger is anywhere threatened by the ditches, either from increase of water or by inundation, from which damage might result, the overseers are required, if the damage might result to but one precinct, to report the danger to the justice of the peace, and if to two or more, to the probate judge of the county.

SEC. 41. The probate judge, or the justice of the peace, shall appoint three suitable persons to make an examination, and if they shall sustain the report made by the overseer, the probate judge or the justice of the peace shall order all persons owning real estate within the limits considered in danger to meet together, and under direction of the overseer or some other person appointed, set about the prevention of damages, by the construction of breakwaters, barriers, or any other work deemed advisable as a means of averting the threatened injury: *Provided*, That the labor shall be performed in proportion to the property of each person interested in the same.

SEC. 42. In all cases where it becomes necessary to take any of the steps mentioned, the person in charge shall direct the labor, notify the parties interested of the number of laborers to be furnished and the part of the work assigned to such parties respectively, and informing them of the place where work shall commence and the day appointed for commencing it: *Provided*, That if after receiving the notice any person or persons shall fail to comply, the person in charge may report to the judge or justice by whom he was appointed who shall cause the delinquent to appear, and fine him in any sum not less than five dollars.

SEC. 43. Every person being a tiller of irrigated lands, who shall have commenced the performance of his part in the common labor on any public acequia, is and shall be obligated to continue on that work until the completion of the cleansing of the acequia.

SEC. 44. If any owners or lessees of lands, shall attempt to abandon their co-laborers without complying with sections forty-five and forty-six, they shall each pay a fine of not less than five dollars, nor more than ten dollars.

SEC. 45. If any person having his fields on the upper portion of an acequia, having reached such fields, shall propose for any cause or causes, reason or pretext, to abandon his co-laborers, or to withdraw his quota of laborers, he shall not be permitted so to do until the completion of the cleansing of the acequia: *Provided*, That touching the repairs and excavations to be made, the proper proportion of labor shall be furnished by the owners, and the majors-domo shall superintend the work as heretofore provided. If in any acequias already constructed there shall be included any dikes and dams which may have been destroyed, and the parties interested in such dikes and dams shall have agreed or contracted to work on the acequia, they shall remain and fulfill their engagements.

SEC. 46. As in the excavation of such acequias, and in the first cleansing of some of them, the work sometimes continues for thirty days, more or less, the different majors-domo shall take into consideration the small amount of land tilled by some, and shall not compel these to furnish as much labor as is required of those having larger interests.

SEC. 47. Every owner or tenant of irrigable lands, irrigated by any of the acequias, shall be compelled to hold at all times during the operations of any acequia to which they belong, the number of laborers to them assigned, at the disposal and order of the major-domo of such acequia, or his assistant, and it shall not be legal for any owner or tenant of irrigable lands, to absent himself for a time exceeding three days without informing the chief major-domo in regard to the persons remaining in his stead, and he shall present them, so that in his presence they may assume the responsibilities during the time of his absence. All the responsibilities of the absentees shall fall on the substitutes, and no other persons shall be admitted as substitutes. And if any owner or tenant of irrigable lands shall absent himself from the precinct during the time the acequias are in operation, without complying with the duty imposed upon him, he shall besides paying the penalty fixed by the major-domo, be responsible for an amount equal to the value of the labor due at a just and common estimate per diem for the time he was absent and for the number of laborers that may have been assigned to him. Nor shall any proprietor, on account of having rented his lands reserving a part for himself, be exempt from working on the acequia at any time of the work.

SEC. 48. This section relates to the penalties for failure to perform work due on an acequia, the disbursement of the sums collected as fines, &c.

SEC. 49. All currents and sources of water, such as springs, rivers, ditches flowing from natural sources, shall be and they are by this act declared free, in order that all persons traveling shall have the right to take water therefrom for their own use and that of the animals under their charge; but the word traveler, shall not in any manner extend to persons who travel with a large number of animals; such persons shall not use the water of any spring belonging to any individual, without having first obtained the consent of the owner. And if any person in transit or traveling, at the time of using any of the water mentioned, shall cause any injury to the fields, to lands under crop, or to other property of any person, he shall pay to the injured party all damages that may have been done: *Provided, further*, That this act shall in no manner apply to wells: *Provided, further*, That this act shall not be applicable to ponds or reservoirs of water that persons may construct for their own proper use and benefit, and no person under pretext of title to the sources, springs, rivers, or ditches, shall have the right to embarrass or hinder, or molest any transient person or traveler in or at the time of taking the water for his proper use and giving water to his animals.

SEC. 50. Hereafter, if any person or persons shall embarrass, hinder, and molest any person or persons at the time they may wish to take water for their animals, and shall claim or demand any compensation for the use of the same, the person or persons so offending shall be fined not less than twenty-five dollars, nor more than fifty dollars, and shall be liable to pay all the damages caused to the person hindered.

SEC. 51. Every person who shall foul the water of any stream, or throw into any ditch, river, or spring of flowing water any dead or pestiferous animal or other filth, dirty vessels, or other impurities that might injure the general health of the inhabitants of any town or settlement, shall be fined not less than one dollar nor more than ten dollars.

SEC. 52. The major-domos of the ditches, and the commissioners of the same, shall prosecute all persons violating the provisions of this act.

SEC. 53. All the salt lakes, with the salt which has accumulated or may accumulate on their shores, are and shall be free to the citizens; and each one shall have power to collect salt on any occasion free from molestation or disturbance. If any person or persons shall prevent, or attempt to prevent, any other person or persons from gathering salt, or going for or returning with it, or if any persons shall arm or embody themselves for any or either of the above purposes, or shall molest, disturb, hinder, or annoy any person or persons while gathering salt, or going to or returning from any salt lake, or shall interfere with the salt gathered, or the animals, carts, or wagons, or any other conveyance used in its carriage, shall be guilty of felony, and shall be punished by confinement in the county jail or Territorial prison not less than two nor more than seven years, or be fined not less than one thousand dollars.

The General Statutes of 1884, in Title XVIII, Chapter II, on municipal corporations, contain, in substance, the following provisions:

SEC. 70. The cities and towns are hereby authorized to condemn and appropriate so much private property as shall be necessary for the construction and operation of water-works or gas-works in such manner as is or may be prescribed by law.

SEC. 71. All cities and incorporated towns constructing water-works are authorized to assess, from time to time, in such manner as they shall deem equitable, upon each tenement or other place supplied with water, such water rents as may be agreed upon by the council or trustees, or upon each vacant lot in front of which the pipes commonly called "street mains" are laid, but such vacant lots as do not take water from the "street mains" shall not be assessed more than one-half as much as may be assessed against the same amount of frontage of lots occupied by a one-story building; and the city or town shall have the power to levy and collect a special tax on taxable property in the city or town, which tax, with the water rent, shall be sufficient to pay the expenses of running, repairing, and operating the works; and if the right to build, maintain, and operate such works is granted to private individuals or incorporated companies, and the cities or towns shall contract with the individuals or companies for a supply of water for any purpose, the city or town shall levy and collect a special tax, each year, sufficient to pay off the water rents so agreed to be paid to the individuals or company constructing the works: *Provided, however*, That the last-mentioned tax shall not exceed two mills on the dollar for any one year.

SEC. 72. They shall have power to construct public wells, cisterns, and reservoirs in the streets and other public and private places within the city or town, or beyond its limits, for the purpose of supplying the same with water; to provide proper pumps and conducting pipes or ditches to regulate the distribution of water for irrigation and other purposes, and to levy an equitable and just tax upon all consumers of water for the purposes of defraying the expenses of the improvements.

SEC. 73. They shall have the right and privilege of taking water in sufficient quantity from any stream, gulch, or spring: *Provided*, That if the taking of the water in such quantity shall interfere with or impair the prior vested right of any person or persons or corporation residing upon such creek, gulch, or stream, or doing any milling or manufacturing business thereon, they shall obtain the consent of such person or person or corporation, or acquire the right of domain by condemnation, and make full compensation for all damages occasioned.

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SEC. 81. This section confers on cities and towns owning water-works the power to levy annually by ordinance a frontage tax on all lots fronting on water-mains within their limits, and to collect the taxes so levied.

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SEC. 1716. Any incorporated town or city shall have power to purchase or lease any canal or ditch already constructed, or which may hereafter be constructed, and to acquire all the rights, privileges, and franchises of any person or persons or corporation owning the same, or having any interest or right therein, and to hold and operate such canal or ditch in the same manner as the persons or corporation from whom the same may be purchased or leased might otherwise do: *Provided*, That the purchase or lease shall be made for the purpose of supplying, by the ditch or canal, water for the use of the people of the city or town; and provided, further, that a majority of the qualified electors of the town or city, who shall vote at any regular election of officers, shall vote in favor of the purchase.

SEC. 1717. Any town or city making such purchase or lease shall assume all the obligations and other duties which devolve upon the owner or owners of the ditch or canal of whom the same may be purchased or leased, and shall have power to repair, improve, or enlarge the same, or any flume, dam, or gate connected therewith, and for such objects may levy and collect taxes. The management of the ditch or canal shall be under the control of the board of trustees, or council of the city or town.

COLORADO.

Persons occupying lands in the neighborhood of streams are entitled to use the water thereof for irrigating purposes, and hence have the right of way to a point of the stream high enough to raise the water to the proper level.

In case of insufficiency of supply, three commissioners, appointed by the county judge, shall apportion the water to different sections on alternate days of the week.

Ditches have the right of way, but two ditches may not be cut through the same land when one can be made to carry the necessary amount of water.

The shortest route must be taken, and the owner must permit a ditch to be enlarged when necessary for the accommodation of other persons, upon payment of a reasonable compensation.

If the channel of a stream changes, the head of the ditch may be changed accordingly. Any person constructing (or enlarging) a ditch must have recorded in the office of the county clerk a full description of the ditch, its capacity, and date of construction or enlargement, and no priority of right attaches until such a statement is filed.

Persons who have used the natural overflow from any stream have in case the supply is diminished from any cause the same priority of right to dig a ditch as if the ditch had been constructed when they first occupied the land irrigated.

Reservoirs for storing any unappropriated water may be maintained, provided that no embankments more than 10 feet high shall be erected without the approval of the county commissioners. The owners of such reservoirs are liable for all damage from breakage or leakage.

Owners of ditches have the right to erect any machinery necessary to raise the water to the proper level.

They shall maintain such embankments that the property of others shall not be damaged, and shall return the surplus water, through a tail-ditch, with as little waste as possible.

Vested right of mill-owners shall not be impaired.

Whenever a ditch crosses a public road the owner shall erect a substantial bridge, and maintain it thereafter. If not built within three days the county supervisors must do it, and collect the cost from the party who should have built it.

Head gates must be kept strong enough to control the water, and the owner failing to keep them so is liable for all damages.

Water rates are fixed and all matters pertaining thereto determined by the county commissioners. The lands of the State are divided by law into different districts, and the governor appoints water commissioners for the several districts, who have general control and regulation of the water.

Any person willfully damaging a ditch or reservoir with intent to injure any person, or willfully opening or closing a water gate without authority, is guilty of a misdemeanor, and subject to fine and imprisonment.

Justices of the peace have jurisdiction of such offenses, with the right of appeal.

Ditches where water is not sold for the purpose of deriving a revenue are exempt from taxation.

There are very elaborate rules with regard to location, priority of rights, and proceedings in court in cases of contests.

TEXAS.

Commissioners' courts regulate irrigation, and establish all needful rules in relation to constructing and keeping in repair ditches, roads, and bridges. They may license any number of owners of arable lands to construct dams, ditches, fences, &c.

Ditches have the right of way. The commissioners may discontinue ditches and dams when the public health requires it.

NEBRASKA.

Irrigation companies may be incorporated under general laws, and are declared to be works of internal improvement, and, as such, towns may vote gratuities to them to the extent of 10 per cent. of the assessed value of such towns, and by a two-thirds vote to the extent of 15 per cent., and may issue bonds for the same purpose to the amount of 10 per cent. of the assessed value.

KANSAS.

Irrigation companies have the right of way through any lands or lots, and, with the consent of the municipal authorities, through any street, alley, or public ground of any city of the second or third class, and may use as much water as is necessary for the purpose for which they were organized, but no injury shall result to milling or other improvements already constructed. Any such company may sell or lease any portion of its water, transmit power by shafting, &c., borrow money necessary for completing and operating its works, issue bonds therefor, and mortgage the company property as security, enter upon any property for the purpose of making surveys, hold voluntary grants made in aid of the construction and maintenance of the works, construct a canal not more than 50 feet wide, and furnish water at such rates as its by-laws may prescribe.

Any person or company furnishing water to irrigate any land shall have a lien for payment upon the crops grown thereon.

Any person willfully injuring any irrigating canal, the right of way having been secured, is guilty of a misdemeanor and may be punished by fine or imprisonment.

NATIONAL LEGISATION.

The following law forms chapter 107 of the acts of the Forty-fourth Congress, second session:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be lawful for any citizen of the United States, or any person of requisite age who may be entitled to become a citizen and who has filed his declaration to become such, and upon payment of twenty-five cents per acre, to file a declaration under oath with the register and receiver of the land district in which any desert land is situated, that he intends to reclaim a tract of desert land not exceeding one section, by conducting water upon the same, within the period of three years thereafter: *Provided, however*, That the right to the use of water by the person so conducting the same, on or to any tract of desert land of six hundred and forty acres shall depend upon bona fide prior appropriation; and such right shall not exceed the amount of water actually appropriated, and necessarily used for the purpose of irrigation and reclamation; and all surplus water over and above such actual appropriation and use, together with the water of all lakes, rivers, and other sources of water supply upon the public lands, and not navigable, shall remain and be held free for the appropriation and use of the public for irrigation, mining and manufacturing purposes subject to existing rights. Said declaration shall describe particularly said section of land if surveyed, and if unsurveyd, shall describe the same as nearly as possible without a survey. At any time within the period of three years after filing said declaration, upon making satisfactory proof to the register and receiver of the reclamation of said tract of land in the manner aforesaid, and upon the payment to the receiver of the additional sum of one dollar per acre for the tract of land not exceeding six hundred and forty acres to any one person, a patent for the same shall be issued to him: *Provided*, That no person shall be permitted to enter more than one tract of land, and not to exceed six hundred and forty acres, which shall be in compact form.

SEC. 2. That all lands, exclusive of timber lands and mineral lands, which will not, without irrigation, produce some agricultural crop, shall be deemed desert lands, within the meaning of this act, which fact shall be ascertained by proof of two or more creditable witnesses under oath, whose affidavits shall be filed in the land office in which said tract of land may be situated.

SEC. 3. This act shall only apply to and take effect in the States of California, Oregon, and Nevada, and the Territories of Washington, Idaho, Montana, Utah, Wyoming, Arizona, New Mexico, and Dakota, and the determination of what may be considered desert land shall be subject to the decision and regulation of the Commissioner of the General Land Office.

ANCIENT ROME.

The following pages present a careful review of the jurisprudence and public polity of ancient Rome, and of several modern states, with regard to the subject-matters of the report. For a considerable portion of the data the Department is indebted to the works prepared by the State engineer of California, Mr. William H. Hall.

Rome, it may be said, once ruled all the countries of Southern Europe, Northern Africa, and Western Asia, where irrigation had its birth and its greatest development in ancient times.* Like air, water was regarded as a necessity to human life, of which every one might use so much as was requisite for personal requirements, but which was not capable of appropriation to private ownership farther than in this sufficient quantity. Streams, rivers, ponds, &c., which were not in private ownership, were regarded as things which belonged to the people as a nation. The roads and rivers were specially counted as public things by the Romans. The codes authorized the use of the rivers as shipways, or for fishing, but the ownership itself was vested in the state. They were not the property of the ruling sovereign, but of the sovereign power of the people collectively, each one of whom could use them as his own, but might not injure, neither segregate any portion or constituent part of them for his own. And this right was extended to all, whether Roman citizens or not, who were at peace with Rome.

Public rivers are defined to be such as were perennial or ever flowing, but if located through private lands were not the property of the public unless navigable or capable of being made so by improvement, or from some other cause of public importance. A river was distinguished from other streams by its greater volume or more considerable local importance.

The bank of a river commenced at the limit of the spread of the waters at high tide, but when lands were not inundated, land below that line was property in public or private ownership. In the case of navigable rivers, and all streams which were public property, the beds belonged to the State. Should the waters leave the channel and take another, the river was considered to have moved, and the old bed became the property of those whose lands were taken for the new channel, while lands taken for this new channel became part of the public property—the river. In the case of non-navigable rivers and streams not regarded as public, situated on private property, the beds belonged to the riparian proprietors. While the beds were covered with water the rights of the proprietors were suspended, but revived when the waters receded. The banks of the public river might belong to the riparian proprietor to the extent that he had the right to take the fruits, cut the bushes, and fell the trees which grew thereon, but not so as to prejudice the use of the river or its banks by the public.

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* Irrigation, of course, existed in some of these countries long before the Roman Empire was founded, and Egypt, India, and China also were the scenes of irrigation practice at a much earlier period.

The public had a right to the use of the banks of navigable rivers, so that a qualified ownership of the soil of such banks was all that could be acquired by private persons. The owner of lands which were bounded by a ditch or wall following near the bank, or by a public road on the bank of a public stream, was not a riparian proprietor; to be such, his lands had to be bounded by the stream itself. Roman law made a marked distinction between rivers and other streams and the waters thereof. A river-bed and the water was each regarded as a public thing, the property of the state, necessarily excluded from private ownership, control, barter, or sale; the use of both was to be enjoyed by all.

The water of the river was the property of the people in common, and each, if the enjoyment of the public property would not be impaired, might divert a portion of the water from its natural channel for other purposes than those of his own domestic necessities.

The state was guardian of the common property, the water, and no person could use more than sufficient for his individual necessities and those of his family and cattle without a special permit. In the case of water sources and water courses which were susceptible of private ownership, the right to use their waters for purposes other than the supply of the immediate animal necessities pertained primarily to the owners.

Springs and brooks being situated on private lands constituted parts of such property, but the water itself while running in its natural channel was the property of all the people. The banks and channels of public rivers were specially guarded from injury; the construction of works or the placing of obstructions, by the effect of which the current might be made more or less rapid, was forbidden. The construction of works upon the bank or in the channel of a public river, whether navigable or not, whereby either the high or low water flow would be affected, was also forbidden, and works which might have an effect such as described, erected without authority, were removed or abolished at the expense of the constructor.

It was declared lawful, however, for riparian proprietors, or those who lived near the bank of the public river, to erect works for the protection of a bank, provided that navigation was in no way impeded thereby, and that the river or the other bank was not injured. If damage resulted from any such work an official examination was made, and the works were removed or ordered changed, and security for ten years was exacted from their owner or constructor. There was a provision concerning the protection of river banks, whereby it was lawful for riparian proprietors to construct works for the repair or protection of the bank adjacent to their property.

If damage was threatened by such works to the lands of another, a writ of inquiry was ordered, and security was exacted for ten years against the results of such possible damage.

The diversion of water, whether of floods or low-water flow, from public rivers reservoirs, or tanks, without the sanction of a special privilege in each case, was prohibited.

The water privileges were of two kinds: first, those granted to individuals, of water for use on individual lands; second, those affecting water for public use. When a joint right to divert was issued to several persons, the division of the water was left to those holding the right. The use to which water was to be put was not always stipulated in grants, provided that it was to be used in good faith and not wasted. The user of water was liable for damages "by reason of anything done, dug, sown, delved, or built, whereby the river was corrupted." It was declared that water privileges should be "exercised in such a manner as not to damage other persons having similar rights."

Immemorial possession and use of running water by a private individual, as for the operation of a mill or in irrigation, gave prescriptive rights to the continued enjoyment of such use.

No possessor of water, though having held it from time immemorial, had the right to use it wastefully to the prejudice of others.

Springs on private lands were the property of the land-owner, on the principle that to such proprietor belonged all above and all below the land and all it produced. The right to use spring water might be acquired by others by agreement or prescription.

Spring waters flowing off, joining with other waters, and forming brooks on other lands, became common property, but their use was dedicated to the owners of the lands along their course, so that such waters for purposes of diversion belonged to these riparian proprietors.

Water rising out of the ground on a private estate, as being a part of the spring, was the property of the owner of the land; but when any portion of such water had escaped from the tract where it came to the surface, it became a common property of all the people. But so long as it remained in channels on private estates only the owners of the banks of its channels could divert it from its course and use it, except this right should have been acquired as a servitude.

But even these bank proprietors could not divert such waters if in so doing other proprietors were injured.

Water drawn from its source or diverted or drawn from its course into an artificial and private channel, or when stored in a reservoir or tank, itself in private ownership, became private property.

The user might do with it as he chose, providing his use was in good faith—not wasteful. The rights to draw waters from a private spring or stream by others than its owners, and to conduct waters across lands owned by others, ranked as servitudes. A predial servitude under Roman law was a definite right of enjoyment in some particular respect of one person's property by the owner of other adjoining or neighboring property. Such a servitude could be held only as an appurtenance to land owned, being called predial because it could not exist without an estate.

The right of passage across the lands of another and the right of conducting water through such lands appear to have been recognized as indisputable privileges from the earliest times of the Roman jurisprudence.

The right of way to construct a canal or other conduit through the property of another, and to lead the waters through it, was one of the chief rural servitudes. The right to take water through the property of another in a ditch or other conduit could be acquired by prescription use for a long period of years, or by agreement, or, in the case of public works, title to the land necessary could be acquired by expropriation and payment therefor. When acquired as a title, of course the right was complete. When as a servitude, the right was accorded for a certain purpose only. A right to draw and use water from another's spring or rivulet might be imposed by agreement or prescription as a servitude thereon.

MODERN ITALY.

"In Northern Italy the waters of all streams, whether navigable or non-navigable, appertain to the royal or public domain." The old established claim of the cities, communes, and associations of proprietors and of noble individuals in Lombardy to the supplies of water which they had for long periods of time actually utilized, having been recognized, the Government asserted and maintained its ownership to all natural streams, whether navigable or not.

Diversions of water under the old claims were subjected to Government regulations, but when the Government had come into control of the streams, so many claims had grown up that the proprietorship of the State was almost a barren one.

In Piedmont the right of property in all running water was reserved to the State. This reservation applied not merely to the large class of rivers, but also to the streams and torrents, the water of which could only be used under specific grants from the Government. After all Italy had been brought under one Government there was promulgated in 1865 the code of Victor Emanuel, of which Article 427 is as follows:

> The national roads, the shore of the sea, the harbors, bays, coasts, rivers, and torrents, the gates, the walls, the ditches, the bastions of forts and fortifications form a part of the public domain.

This provision of the code of 1865 is the law now in force in Italy, and under it all running waters, except those of very small streams, are claimed as property of the Government, representing the people as a nation; and they are administered very much as are the waters of the navigable streams of France.

Navigability itself was a ruling consideration in France, while a volume of water for irrigation was the point of importance which made the stream one of public utility in Northern Italy. As a matter of fact, in Northern Italy every stream of perennial volume, other than very small streamlets, is regarded as a river; and every stream of intermittent flow from the rainfall or melting of snows, except the smallest, is regarded as a torrent.

The principle that ownership of the land carries with it all beneath its surface and all it produces has prevailed from the times of the earliest recorded laws in all the north of Italy. Waters rising out of the soil have always been regarded as the absolute property of the owner of the soil so long as he retained them within the bounds of his estate and did not permit his title to suffer abridgment by allowing some other proprietor to acquire a prescriptive right to the use of the waters. The springs always remain the property of the owner of the soil, but the right to use their waters may be wholly alienated and held by the owner of some other property. The principle as to ownership of a spring is the same in all Italy as it was for Piedmont and other parts of the Sardinian Kingdom.

As the law now stands in all Italy, the owner of one or both banks of a little stream may use its waters in irrigating his riparian lands, but he must restore the drainage and residue of it to the ordinary channel; while he who is not a riparian proprietor cannot take such waters at all without the consent of all the riparian proprietors; nor can any one riparian proprietor assign his right to water from such a stream to any one else.

The riparian right to divert waters from a stream is confined to the case of very small streams, and is scarcely known in the valley of the Po. During the times of the ownership of the streams and waters by the sovereigns of the states, and by the petty feudal rulers, and by the sovereign powers of the states as the representatives of all the people in each case, the right to divert water from any river or torrent could only be acquired in the states of Northern Italy by special grant or concession of privilege made on a formal application, after due examination and consideration of all the interests to be affected. And now that the country is united under one Government, and the waters belong to the royal or public domain, the same rule, and substantially the same formalities in applying it, exist.

It appears that the policy of the rulers in Lombardy, until the later years of its existence as a separate state, has generally been either to dispose of the waters of its streams in absolute property by gift or sale to those who constructed the canals to lead them out, or itself to construct such canals and sell the waters directly, or indirectly through farmers of the canal revenues, to the irrigators. The Government of Piedmont has generally been more conservative in the care of its waters. Absolute grants of ownership of waters ceased in that country before the beginning of the present century. Water privileges for all time have been issued, but the full right of regulation was reserved to the Government, and the cession of proprietorship in the water was expressly disclaimed. There are, however, important works whose proprietors have absolute rights of ownership in the waters, acquired in the centuries gone by. During the later years of the existence of the Piedmontese Government its waters were disposed of only on long-term leases. This last-mentioned policy is that pursued by the Government of Italy since it has supplanted those of Lombardy and Piedmont, the duration and terms of concession being similar to those of France.

FRANCE.

While under the dominion of Rome all matters pertaining to the streams and waters of the country now called France were subject to Roman law. Long before the close of the Roman rule the people had the full protection due citizens of Rome, so that at the time of the conquest of Gaul by the Visigoths (A. D. 470 to 480) there was much land held in individual ownership, with the consequent private rights, on small streams; but under the Merovingian kings the freehold titles to land disappeared, property was held by a different tenure under the sovereigns, and all rights of ownership in water-courses and waters was vested in the rulers themselves. The feudal system then grew up, and the water courses, from having belonged to the nation and the people, or to private individuals, under Roman law, and then exclusively to kings under Merovingian rule, became dependencies upon the liefs of the feudal courts, who assumed almost complete ownership of and control over them. A struggle was ever present between these nobles and the kings for the control of the water-courses, and the conflict did not cease until the Government had become centralized and feudalism overthrown, during the fourteenth century. In that century the study of the Roman law was actively reviewed in France, and feudalism being on the decline, the Roman law recognizing ownership of streams not of public importance, non-navigable streams, by the riparian proprietors became incorporated into the law of France.

The kings asserted their ownership of all navigable streams and left the control and virtual ownership of non-navigable ones to the bank-owners, but really without any formal laws upon which to ground their claim of title to them. The public possessions of the kings held for the benefit of the nation became known as the "public domain." This policy of holding fast to all the nation's property is still adhered to by the Government, so that water-courses and waters once declared navigable and raftable can never be alienated from the public domain and become in any sense private property.

The changes in the form of government occurring a little less than a century ago appear to have resulted in no completed action affecting the laws or customs respecting waters until 1803-'04, when the Code Napoleon, which is the present civil code of the country, was promulgated. The only direct statement relating to the ownership of water-courses or waters in this code is as follows: Highways, roads, and streets at the national charge, rivers and streams which will carry floats, shores, ebb and flow of sea (the land newly made by the sea), ports, harbors, roadsteads, and generally all portions of the national territory, which are not susceptible of private proprietorship, are considered as dependencies on the "public domain." A royal ordinance of 1835 enumerated all the streams and parts of streams in France deemed navigable and claimed as of the public domain, and other ordinances of later dates have added to the list.

The sovereign authority to declare streams navigable, and hence part of the public domain, has not been disputed, but riparian proprietors who have been dispossessed of their right to water for irrigation, by the exercise of this power, have claimed and been allowed indemnities for actual damage caused them. Although only certain streams and parts of streams have thus far been added to the public domain, the administration may at any time declare other streams or parts navigable or raftable, and thus make them public property, afterwards paying the riparian proprietors for actual damage. The state owning these water-courses is, of course, owner of the waters forming them, and these, with the beds, are alienable from the public domain; their use only can be granted. According to the terms of the civil code, water-courses not navigable are common property. If the ownership of non-navigable water-courses cannot be fixed elsewhere, then these streams belong to the nation, just as well as do those which have become part of the public domain.

Riparian proprietors claim the ownership of the channel bed to the center line in front of their property, and the claim is allowed, when the beds are permanently laid dry from any cause; alluvial deposits along their banks accrue to the benefit of the land-owner adjacent to whose field they form; islands forming in the channels belong to the adjacent bank-owners, and prior to the passage of a law specially to the point in 1847 the owner of one bank, although he might have secured administrative authority to build a dam in front of his own property, could not carry it past the center of the stream, or connect it with the opposite bank, without the consent of the bank owner. Until very recent years the beds of streams of this class belonged to and were under control of riparian proprietors, except where the Government has exercised a supervision of works and channels to insure a free flow for flood waters.

The waters of non-navigable and non-raftable streams were formerly claimed as the private property of the riparian proprietors. Their origin and division and the necessarily common control of the streams upset this theory. Then they were claimed by these proprietors as a sort of property held in common by them for the exclusive benefit of their lands and industries. It was and is still claimed by the owners of lands not bordering the streams that the waters belong to the whole people of France; and while the riparian proprietors are given a right to use them in irrigation and otherwise, it is not exclusive, but the Government can grant concessions for the use of some part of them on lands not riparian, so long as rights already accrued by use be not unduly or injuriously limited or their exercise inconvenienced by such action. The riparian proprietors now say, if the waters belong to the nation, they, the bank-owners, have a special and complete servitude on all such waters, which right to use is continuous and not forfeitable by failure to avail themselves of it at any time or any length of time, except as between themselves. The fact of the ownership of the waters of non-navigable and non-raftable streams by the nation is now pretty well settled, and the tendency of decisions is towards a declaration of ownership by the nation of the beds also so long as occupied by the waters —so long as they are courses for public waters.

Starting several centuries ago with almost complete ownership and control of the waters and channels of the streams not navigable nor raftable the riparian land owners have since been restricted in their rights, and now find themselves without any recognized claim of ownership in the waters, and only a semblance in the channel beds, until after these shall have been laid dry, but with a preferred privilege to the use of the waters.

We find irrigation constantly favored in the laws in preference to manufacturing and many other uses of waters, domestic necessities and navigation alone ranking it in the scale, and the first of these two uses being the only one decidedly preferred to it in the administration of the laws.

On non-navigable and non-raftable streams the administration in the theory interferes with private operations conducted by those who as bank owners have rights on the streams under the ancient usages and civil code to regulate works in the channels or on the banks with a view to preserving the channels in the interest of the public and for developing a free passage for flood waters, and with the view of preserving the interests of navigation on the main stream below.

On the water courses of the public domain the policy of the Government is actuated by a solicitude for the interests of navigation, and then by an almost equal interest in promoting the economical and full use of the waters in agriculture, manufacturing, and industrial pursuits generally, and finally by a realization of the pressing necessity for promoting the arterial drainage of the country, in order that floods may be prevented and valuable lands reclaimed.

On non navigable water courses the administration is not authorized to interfere between the owners of works already constructed and those proposed or newly constructed. The administration is bound to presume that the proprietor of lands on streams has a right to water therefrom, and can only interfere to the extent of regulating his works. The engineers can advise the parties in interest and bring before them all the facts as to measure of water supply and extent of use, &c., but if on such showings agreements cannot be arrived at, the administration has no alternative but to sanction the construction of any new work proposed, provided the work itself is unobjectionable, leaving the court to decide whether or not the new appropriator is entitled to water. On navigable streams the administration is invested with full powers, not only to regulate works of all kinds, but to consider all questions relating to water privileges. In case of both classes of streams the engineers are charged with the duty of collecting and arranging data respecting the supply and use of waters.

The construction and management of all public works except those specially confided to the minister of war, of the navy, of education, of posts and telegraphs, and some others are delegated to the secretary of state or minister of public works. The care of all waters and water-courses, whether of public domain or not, their control and the control of the acts of individuals on their banks are regarded as of public concern, and the administration thus has to do with all affairs affecting streams. It is now the intention of the Government that all water-courses of public importance in France, whether navigable or raftable, and consequently of the public domain, or not floatable even for rafts and timber, but which are of public utility, shall be subject to the supervising care of special agents of the Government called guards. On non-navigable streams the guards are generally appointed on recommendation of the riparian owners, and others interested.

No work of any kind, sort, or description may be erected upon a navigable stream or river floatable for rafts, or timber, or upon any stream so declared, nor can any water be taken from such streams, except it be taken in a bucket or other similar hand vessel, without the project for which it is required and the plan by which it is to be constructed, if a work, or used, if a water privilege, having been first submitted to the administrative authority and publicly made known, so that it may be opposed, if necessary. Older rights and those of industries most needful are always protected in the administration of affairs from day to day; but no right is so old or use so pressing that its owners have the power to control the diversion of the people's water, or use it in a wasteful manner, or in any way hinder the full development and prosperity of other institutions dependent on water supply.

It is on rivers and portions of rivers where it has become necessary to construct dams for navigation, and those still higher, which have been dammed for purposes of flotation, that water privileges are chiefly sought after for power purposes, irrigation, municipal supply, and industrial use. Such water-courses are public property, under full control of the administration. Non-navigable tributaries of navigable streams, and these streams themselves above the points where they become navigable, are also under the control of the administration. Still or stagnant waters, those draining from marshes and ditches, that have free communication from navigable or raftable streams, and whose waters flow the year round, or waters where ferry-boats can enter at all times, and those cared for at the expense of the State, make part of the public domain, and a right to dispose of or use them may be had only by special authorization.

Projects requiring special privileges to use water or sanction of plans to erect works in water-courses are undertaken either as private enterprises of individuals to water their own lands, to run their own mills, or for other private purposes, or as speculative enterprises by individuals, associated landholders, or capitalized incorporated companies desiring to sell water to consumers. When water privileges or permits to construct works are desired by individuals for their own private benefit in the use of water or otherwise, on navigable streams, an application must be made to the prefect of the department where the intended work or diversion is to be made.

When water privileges on streams navigable and of the public domain are desired by individuals, companies, or societies, for speculative purposes, all permits or concessions have to be acquired by decree deliberated upon in the council of state. Whenever possible, the diversion of water for an irrigation canal or other use (requiring the construction of a dam in the river) is effected by a work which serves at the same time to hold back water for the promotion of navigation. Works designed for taking water for any purpose of a holder of a water privilege are always constructed and maintained at his expense, and when in close connection with a dam for navigation purposes, are carried out by the administration. Upon non-navigable water-courses which have not been declared to be dependencies on the public domain, in the civic code, and which have not been improved in the interest of navigation, the expense of cleaning and caring for the channel generally is borne by the riparian land owners.

Works erected and acts committed in the channels or on the banks of non-navigable or non-raftable water-courses, when they present no obstruction to free flood flow, are subject to regulation by the law as administered by the courts; but works located upon navigable streams, when not duly authorized by the administration, constitute infringements of the authority of the commission of public ways, and are subject to repression. Water privilege rents for irrigation works are rated upon the basis of the increase in yield due to irrigation, and are fixed at a sum annually paid, equivalent to one-tenth of the increase in value of produce on the land irrigated over its produce before irrigation.

Without meaning to limit the duration of water concessions, the rents are revised every thirty years, for, though revokable at any time, water right concessions on public streams are given for an indefinite time. Water-privilege heads held in private control previous to the edict of 1566 declaring the inalienability of the public domain, are free from the charge of rents, as are also those whose holders have titles derived by purchase from the Government.

The exclusive right to water for milling and irrigation purposes from streams too small to be regarded by the kings as of public importance were accorded to the owners of the bank lands, apparently on the ground that they owned the beds and waters as well as the banks, previous to the time of the Code Napoleon. In later years it appears to have become recognized that the waters were in reality a common property, and that the bank proprietors had only a right to use them and not a right of ownership in them.

Still there was the open question, to whom were the waters a common property; the riparian proprietors claiming to be the owners in common of the waters of each stream, and submitting to the control of the streams by the Government only as it was based upon the general police authority of the nation; while the Government asserted its right to control, not only because of its general police powers, but because of the fact that the waters were really common property of the whole people, and not of the riparian proprietors alone, and that public interests were to be promoted, as well as other private interests guarded by it, and that its mission was one to promote public utility as well as repress or prevent abuse of private privileges in the protection of other privileges.

The continued and growing abuse of the riparian water right privilege brought about an increased necessity for upholding this latter view, so that it became a popular sentiment, and owners of lands not riparian to the streams asserted a right to the waters for their irrigation on the ground that such waters were a common property of all the people; and asserting that the riparian owner's privilege of using them was not an exclusive privilege, but that upon a grant or permit from Government any land owner could divert them for use on his lands. In this view of the case by far the greater number of land proprietors were interested, so that the governmental policy of control was strongly upheld. Now the manufacturing interests took alarm. The owners of the hundreds of mills and manufactories depending upon water supply for power and other purposes scattered along the streams all over France, and holding rights, many of them dating back in the times of the counts, and all valuing the riparian right as a protection to their water supply, were arrayed against the advancing theory of the waters belonging to all the people and due to all the people for use. The Government continued to uphold the theory of the waters of these small streams being a common property of all the people, but no step was taken to accord land owners other than riparian proprietors any right to use them.

The case appears to have stood this way when the Code Napoleon was promulgated in 1804. This code contained provisions which in course of time were recognized as placing the ownership of the waters of the smaller class of streams in the nation, but declared the use of things of this class to be common to all. Left with this provision only, the waters of these streams would have been thrown open to use by all the people. But an article, under the head of "servitudes," seemed to place a special servitude (right of use) on these waters for the benefit of riparian estates. The Government had its hands strengthened in its policy of control and regulation, and the fundamental principle contended for by the owners of lands not riparian, as well as by Government, was recognized.

The ownership of water belongs to the state, without prejudicing the right to the same which corporations or individuals may have acquired by legal title in conformity with the provisions of special laws in relation to public real estate. The enjoyment of the ownership of water is subject to the following provision: No one may use the water of the rivers in such a manner as to obstruct navigation, nor construct in them works which hinder the free passage of vessels or rafts, or the using of any other means of water transportation. In a similar manner the hindrance or obstruction of the use of the banks is prohibited when they may be necessary for the same ends.

The proprietor of water, whatever may be his title, has no power to hinder the use of so much as is necessary for the supply of persons or stockmen who are in possession of or living on real estate; nor to oppose the indispensable works to provide for that necessity in such a manner as shall be the least burdensome to the proprietor. He may have the right to indemnity reserved, except from those inhabitants who have acquired the use of water by prescription or by other legal title.

The provisions of this code relating to the servitudes of water shall not interfere in any manner with rights legally acquired up to this date concerning the same.

The proprietor of water has no power to divert its course in such a manner as to cause damage to a third party from overflow or from any other cause. If any person dig a well on his premises, notwithstanding he may diminish the flow of water upon the adjoining land, he is not obliged to give indemnity. Every one who has acquired water, the use of which he may dispose of, has the right to pass through the intervening lands, subject to the obligation of indemnity to their owners, and also to the owners of any lower lands upon which the water may leak or descend; but edifices, their courts, gardens, and other appurtenances are excepted from the servitude established by the foregoing provisions. He who has the right of use has the right of way for water, and is obliged to construct the necessary channel through the intermediate lands, although there may be other channels for the use of other waters. He who has on his lands a channel for the use of water which belongs to him may prevent the opening of another, offering to give passage through his own channel, provided it does not cause damage to the claimant. He must permit the passage of waters across canals and aqueducts in the manner most suitable to the course of the waters which are to be conducted by them, and the volume must not be altered nor the two waters mingled in both aqueducts.

In the case of right of passage through intermediate lands, if it becomes necessary to conduct the aqueduct over a road, river, or public stream, it is indispensable that permission should be previously obtained from the authority to whose care the road, river, or stream is intrusted. Such authority shall only grant permission, subject to regulations binding the owner of the water for which passage is sought, not to hinder the passage of the water, nor injure the highway, nor interfere with or stop the course of the river or torrent. He who without previous permission makes a passage for water or causes it to flow upon the highway shall be obliged to restore it to its former condition, and give indemnity to any one to whom damage may have been caused, in addition to paying the penalties imposed by the public regulations.

He who seeks to use the privilege (right of way through intermediate lands) must previously, first, prove that he can dispose of the water which he claims to conduct; second, affirm that the route which is solicited is the most suitable and the least burdensome, to third parties; third, pay the value of the land which he shall occupy by the canal according to the estimate made by experts, with an addition of 10 per cent.; fourth, compensate for all immediate damages, including those which will result from dividing the land into two or more parts.

Where the use of a canal already built is offered, he who claims the passage of water must pay in proportion to the quantity of the same and the value of the land occupied by it and the necessary expenses for the preservation of the canal, without prejudice to the indemnity that must be given for any other expenses which may be occasioned by the passage which is to be conceded.

The quantity of water which may be passed through the aqueduct established on the adjoining land shall have no other limitation than that which results from the capacity of the water-way as determined by its dimensions. Should the person enjoying the use of the water-way be compelled to enlarge it, he must bear the necessary cost, and pay for the land which is merely occupied, and for any damages caused. The damage is to be estimated by experts with an addition of 10 per cent., and account shall be taken of both immediate and resulting damages. The legal servitude before mentioned carries with it, subject to provisions hereinafter contained, the right of way for persons and animals and the transportation of the necessary materials for the use and repair of the water-way.

The provisions and same laws concerning the passage of water are applicable to marsh lands requiring drainage or an outlet. The concessions which may be obtained from the competent authority are to be without prejudice to other rights previously acquired. Every one who has the use of an aqueduct, whether it passes through his land or through lands adjoining, must construct and maintain the bridges, canals, aqueducts, subterranean and other necessary works, so that the rights of others may not be prejudiced. Those desiring to enjoy the use shall pay in proportion to that enjoyment, if there be no prescription or contract to the contrary. The code contains provisions for keeping the water pure and for the construction of such works as may be required, in order that the course of the water may not be interrupted.

The owner of land subject to the servitude of right of way may designate the place in which the servitude shall be constituted.

If the proper judge shall decide the place to be impracticable or very burdensome, the owner of the land must designate another. If the place is subject to the same objection as the first, the judge shall designate one which shall be established, taking into consideration the interest of both properties.

If there are several pieces of property through which must be given a passage or a public way, the servitude shall be that of the shortest distance. If the distance shall be the same upon the properties, the judge shall designate through which of them it shall be given passage

The width of the right of way shall be such as the necessities of the case may be deemed, in the discretion of the judge, to require, but shall not exceed 5 meters nor be less than 2 meters, without the consent of the parties interested.

The court of cassation and the council of state have each decided also that the fall or slope of a channel is not the property of the land proprietors, and that it enters into the class of things which, by the terms of an article in the Code Napoleon, do not belong to anybody, the use being common to all, and the enjoyment regulated by the police laws; hence the administration grants a proprietor the right to back water into the channel in front of lands above him by means of his dam, so long as he does not injure or endanger the lands in any way. Here, again, was a step towards the abolition of the exclusive riparian control of the smaller stream, and a movement towards declaration of public ownership of the channels themselves. And thus the matter stands. The riparian proprietors still monopolize the right to use the waters from streams of this class. The code merely gives every riparian owner a privilege of using the water. No matter how old a privilege may be, the administration in the public interest has always the right to turn sufficient water past the dam to satisfy the personal wants of proprietors below, and it can even compel the construction of a sluice-way in the dam to be used for this purpose.

As a matter of fact, the streams are controlled and the waters apportioned out to those who have claims on them by administrative regulations. The matter of the ownership of springs has been one full of contention in France; but it is now well settled by the provisions of the code and the decisions under it. He who possesses a spring within his field may make use of it at his pleasure. The code defines certain circumstances under which the control of springs is limited and qualified, the causes being the necessities of communities for water for domestic purposes, the necessities of the State for water for purposes of navigation, the rights which persons other than the owners of springs may have acquired by purchase or by prescription. The courts can, in the interest of agriculture in general and for the benefit of local agriculturists, prevent wasteful or selfish use of spring waters.

The ownership and control of springs is so complete and absolute that so long as the waters remain within the property where they rise, even though used as power for manufacturing purposes, or otherwise, the administration can do nothing to interfere with the proprietor's use of them.

But if spring waters be led across or into property other than that containing the source, for whatever purpose, the stream is subject to regulations, as in the case of others. The owner of a spring cannot change the course of its waters when they furnish the necessary supply to the inhabitants of a commune, village, or hamlet.

Government can take possession of springs to feed canals for navigation, but on condition that it pay a just indemnity.

The absolute right of ownership in a spring is also modified by purchased titles, by prescription, and by servitude set up by the division of an estate containing a spring.

SPAIN.

The Spanish law of waters, as it now exists, is a code in itself, which was finally determined and promulgated in 1866, after a study of the whole subject for eight years by a commissioner appointed for the purpose. The law of 1866 comprehends all that is treated in laws of various kinds relating at all to waters, high seas, sea-shores, beaches, bays, rivers, &c. The Spanish law makes the broad distinction between waters on private and corporate property, which it calls private waters, and those on the public domain, which are called public waters.

With respect to the acquirement of right to divert water for irrigation from streams on private or corporate property the law may be summarized as follows: waters which rise on private property belong to the owner of the property, provided he does not forfeit his right by non-use for twenty years.

Waters running through private property are private waters, subject to use by owners of the banks. They may appropriate them for the purpose of irrigation on their estates, to be taken in their order from the head of the stream down.

Works for the diversion of waters from a private stream may be constructed by the owner of the banks without official sanction, provided always that the amount of water to be diverted does not exceed 10 liters (about one-third of a cubic foot per second) in any one instance; but, if the proposed diversion exceeds this amount, notice must be given through the alcalde for the information of the governor of the province.

This notice is given for the purpose of setting before the people the facts in the case, and in order that an investigation may be held, which will determine whether or not the proposed appropriation will interfere with existing rights.

The waters of public streams are held to be the property of the kingdom. It is necessary to obtain an official sanction or grant of right before such waters can be diverted and used in public or private irrigation enterprise, except where the quantity diverted by any one appropriator does not exceed 10 liters per second, or where it is to be abstracted from navigable rivers by pumping machinery, or when the water appropriated is only the rain or storm water which drains rapidly away in the torrent beds. This grant of right is accorded only after extended and minute examination of the proposed project by the provincial authorities, and after hearing all that may be said by those whose interests may be opposed to the diversion. There is no such thing as unlicensed appropriation in large amounts, and no such thing as unregulated diversion of waters from the streams.

The waters are held by the Government for the use of the people. Under the Spanish law water is diverted for irrigation in large volumes from the public streams, but it is done under special sanctions from the authorities of the district, in a manner not to interfere with or injure other persons dependent upon its use.

MEXICO.

The problems of rainfall, water supply, and irrigation are of primary importance in the Republic of Mexico. A study of the laws and systems pursued therein is of the greatest importance to American engineers and agriculturists engaged in the practical work of irrigation. Mexico is essentially a dry country; its cultivation is dependent on artificial distribution of water. Its indigenous vegetation presents all the characteristics of an arid region. From all historical evidences it is seen that irrigation was among its earliest necessities and was the most prominent care of its people, of whatever race or condition. The soil of Mexico, as well as of that portion of the United States which formerly belonged to our neighboring Republic, is fertile and fruitful when once vitalized by the application of water. The table lands are everywhere adapted for grazing, and water can generally be found in quantity sufficient for the use of cattle. The forests are valuable and abundant. That an increase in water-storage capacity would largely add to the agricultural value of Mexico is obvious, and such an increase is becoming especially necessary in connection with the construction and maintenance of railroads.

Mr. J. H. Goodspeed, auditor of the Mexican Central Railway Company, writes the Department as follows:

> The sources from which the water supply is derived along the line of the Mexican Central are springs, wells, storage reservoirs, and permanent streams, and these are all dependent upon the annual rainfall. In most cases the supply of water at our water stations is obtained from wells dug by the company, and these vary in depth from 20 to 300 feet, and the water is raised to the tanks either by hand or steam pump. In a few cases they have springs that afford a gravity supply, but they are very few. In order to preserve the rainfall, storage reservoirs have been built, from which the water is distributed by open canals or ditches, and in many places extensive aqueducts of masonry have been constructed to convey the water across valleys so as to utilize it for irrigation. This system of irrigation, by means of storage reservoirs, can to good advantage be greatly increased, as where land can be irrigated two crops a year are obtained; but at the present only a small portion of the rainfall is utilized. The season known as the rainy season lasts some two months, and is for the most part confined to the period between June 15 and September 15. The following will show you the average amount of rainfall at the city of Mexico for seven years and the State of Aguas Calientes for fifteen years:

Months.	City of Mexico.			State of Aguas Calientes, fifteen years.		
	Total number rainy days in seven years.	Average number rainy days.	Average quantity.	Total number rainy days in fifteen years.	Average days.	Average quantity.
			Inches.			*Inches.*
January	16	2	0.2	35	2	.38
February	15	2	0.1	25	2	.29
March	32	5	0.4	27	2	.17
April	40	6	0.3	8	1	.05
May	94	14	2.6	78	5	.74
June	136	19	3.9	162	11	3.62
July	167	24	4.5	216	14	3.89
August	149	22	5.7	219	15	4.66
September	115	16	3.8	173	12	3.84
October	76	11	1.1	90	6	1.29
November	32	5	.4	42	3	.34
December	15	2	.2	35	2	.43
	887	128	23.2	1,110	75	19.70

> The only artesian wells on the line of our road are at the city of Mexico, where good water is found at the depth of from 200 to 500 feet below the surface. These wells are usually flowing, but with only a small head, and have to be pumped when a large supply is needed.
>
> The laws and customs controlling water in Mexico, so far as our road is affected, require the provision of suitable passages for all water used for irrigation.

On February 14, 1856, a law was enacted controlling the distribution of water. The old unit of measure for water was the surco (or sulco) in the country, and the paja in cities, but an act of March 15, 1857, put the French metrical system in force in the Republic, and a decree of August 2, 1863, made the liter (0.26417 gallon)* the unit of measure for water, fixing upon 6½ liters per second of time as the equivalent of a surco (or sulco), and forty-five one hundredths of a liter per minute as the equivalent of a paja of the old measurement. In cases of legal contest, wherein a right to a certain quantity of water was claimed under prior titles, or documents, sanctioned by law, the measurement was still to be given in surcos.

Engineers and surveyors were required to have regard, whether in city or in country, to the degree of inclination (amount of fall) in water channels, to take into account in each case the amount of pressure, and to present in their statements both the formulas employed and the reasons for their calculations.

The royal instruction of October 15, 1754, was passed to regulate the sale and distribution of land and water rights in the Indies. Subdelegates were to be appointed by the viceroys and presidents of the royal audiency, who were to have jurisdiction of such matters, and they were directed not to disturb possessions in lands embraced in settlements, or on which labor had been expended, or which were cultivated or utilized for pasturage. It was also required that all persons who desired to possess royal grants of unoccupied lands and water, and those owners who had possessed, without occupation or cultivation from the year 1700 up to the date of the instruction, should present themselves before the subdelegates and prove their titles within a period of time to be designated by the same authority; and when they had titles to allege which were not yet confirmed, but were issued before the year 1700, they were to be allowed pacific possession in conformity with the law. They were, however, required to register the title. From those who had no title there was required a sworn declaration of long possession, which was allowed to stand as a just title by prescription. Those who desired to acquire title were required to expend labor upon, cultivate, or occupy the grants for a period of three months; and if the period expired without the requirements having been fulfilled by the grantee, the grant might be denounced by any one who fulfilled them.

It was also provided that possessors of lands sold or distributed in or after the year 1700 should never be molested, and their titles were thus confirmed; but those who did not possess their property as aforesaid were required to solicit confirmation of their titles from the audiencias of their district or from the proper authorities, and if they failed to do so within the period designated their possessions were forfeited to the crown, although labor might have been expended on them.

The guiding and fundamental principle throughout the whole of the regulations will be found to have been that all such property was annexed to or incorporated into the royal crown to such a degree that in order to hold possession it was necessary that individual possessors must have alleged and proved that their water rights had been conceded by special favor, because the law declares that to the prince, and to no other, appertained the right of distribution of water. This is still the controlling principle of Mexican law.* The waters must remain under the sole and absolute dominion of the sovereign, all waters of the public rivers (or water-courses of public and common use) being his rights. This principle was so far qualified that any one might take what he needed for domestic use, but no one could take public waters upon his private grounds for irrigation without royal permission. A torrent is a stream of water originating from snow and rain at certain seasons, that is, when the snow and rain raise the streams. Rivers are divided into public and private. The public river is one where all enjoy the right to fish. The private stream is one by which some contract or agreement has become private property, and differs in nothing from other private property, and in describing it "it has no banks." Banks are the precise limits between which the streams run in their natural course, which are as the shores to the sea. In concession of land, if concessions are made jointly of the waters originating upon it, they are appurtenances of the lands granted. Being a servitude, waters had their place among the royal country servitudes. Fountains and springs belong to the owners of the lands in which they rise as parts and appurtenances thereof, for which reason they are conceded with the lands.

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* The metric system is founded upon the meter (about 39.37 inches), which was intended to be the ten millionth part of the distance from the equator to the pole, measured over the surface of the earth, but in reality differs slightly from this measurement. The liter is a cubic decimeter, the decimeter being the tenth part of a meter.

The unit for land measure is the are, which is a square having sides of ten meters in length. The hectare (100 ares) is about 2.471 acres.

A servitude is the right of doing something on the land of another, or of preventing the owner from doing something.

The servitude is a property appertaining to the thing, so that it adheres to it, no matter who may be the owner. Servitudes depend on the proximity of two predial estates, that of the person entitled to the servitude, and that of the person who has to submit to it. If for the enjoyment of the servitude the estate on which it is imposed requires some repairs, they must be done by him entitled to the servitude. The right of servitude is not susceptible of division, but its enjoyment may be limited to days, months, &c. Such rights are acquired in the same manner as other property, and are either continued or interrupted; continued servitudes are those which may be used daily, interrupted ones, such as cannot be so used.

In connection with the use of water there are both urban and predial servitudes.

The predial servitudes relating to water are, first, the right of conducting water by means of canals or pipes over the land of your neighbor for the purpose of driving a mill, or of irrigating your land; second, the right of drinking out of a fountain, or of watering there your cattle.

The servitude of the aqueduct is the right of conducting water upon the ground or field away from the stream for irrigation or other use, specified in the right of servitude, which carries with it the right of way for the water pipes, &c., and for those who have the care of them.

It is unlawful to construct any work damaging others. If the construction of any work on the banks of a stream causes damage to the lands of a neighbor, the law gives him a right of action for the damage occasioned, and the works constructed must be removed.

He who alleges his servitude is obliged to prove it, possession is not sufficient; the right must be acquired in one of three ways: by agreement, by inheritance, or by prescription. It is unlawful to alter the natural course of a stream to the prejudice of third parties; but a person through whose ground the water is conducted may alter the channel for the sake of its more convenient use upon his land, provided that other parties be not prejudiced thereby.

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*The rights of the prince descending to the Government of the Republic.

A servitude may be constituted not only at the source of the water, but upon any part of its course. It may be for a continuous flow, or a flow at certain intervals of time—that is, stated days or hours. The examination of springs must be made by experts, whose report must state under oath that the truth has been faithfully given, without favor toward either of the parties.

The measurements for distribution are regularly obtained from the examinations, or measurements to determine the amount of the natural flow, the distribution being made to each person according to his position on a line. Hence, in measurements of examination, no changes are made, whereas in those for distribution the water-ways are enlarged, diminished, and changed to conform to the letter of the grants of water. Measurements of examination are to be conducted at the most favorable distance from the reservoir or ditch, so that the water may run as nearly direct as possible and without too great rapidity of current. The reservoir shall be made in conformity with some geometrical figure by which its area can be calculated, to which shall be applied a marking-board in such a manner as to show the quantity of water that is withdrawn. The marking-board shall have marginal numbers showing the available height of the water, so that by multiplying this by the width the area of the vertical section may be formed. It is to be understood that water must always be taken in the manner in which it has been from the beginning, so that no more can be taken, nor can it be taken by any longer route. Those who are in possession of a water servitude must be maintained and protected. In order to constitute such a servitude the flow of water must either be continuous or at certain intervals of time.

Dominion cannot be exercised upon the lands of another unless distributing tanks or aqueducts are built with separate basins, with apertures in the sides, having gates of the proper size to give to each the quantity to which he is entitled. If the form given to the aperture is that of a square, the area being given, the square root shall be the diameter of the orifice. If it should be circular, the diameter may be found by the rule of Archimedes, that as 11 is to 14, so is the area of the figure to the square of the diameter, the square root of which is the diameter of the required orifice.

In distributing water from basins or reservoirs all the parties interested must obtain their amounts from apertures at an equal depth, although the sizes of the openings may be different. In taking water from a horizontal canal, through orifices in its vertical sides, a stop of the same size and figure as the opening must be set into the wall on the side of the opening towards which the current runs, so as to drive the water into the orifices.

When various parties participate in the distribution of water, all tanks and receptacles and all openings for drawing it off should remain unchanged in their dimensions and proportions, so as to preserve to each the quantity publicly granted. The builder of such tanks and orifices shall be the judge of the shape most suitable, but they shall have a uniform altitude, increasing or diminishing the bases, if rectangular, but if circular their centers must be on the same horizontal line. It is an inflexible rule that the water which issues from these apertures should have the same fall, for two reasons—they start from the same level line of base; or, if they take water from a fall, it is from the same apron-stone upon which the waters fall, although carried away from thence in different troughs or chutes; the gravitation of water increases its velocity in proportion to the distance through which it falls. The point of delivery must be below that of the source. The surface of the water curves to correspond with the surface of the terrestrial globe, and in using a level, to avoid the error of assuming the water-level to be a straight line, the instrument should be set in the middle of each stretch of the line to be leveled, which may be longer or shorter according to the slope of the ground. All the proprietors who participate in the benefit derived from the works which have been treated of are under obligation to contribute to the payment of the expense of their execution in proportion to their interest, according to an appraisement by experts. Those who by their own culpable negligence have occasioned any damage must be responsible for it.

The owner of land in which there is a natural fountain or source, or who has dug a running well, may cover it, or confine it by a pond or dam, to detain its running waters for his own ground, and may use and dispose of the waters freely. If he have surface waters which pass upon another piece of land, the owner of such land, upon the lapse of twenty years, reckoned from the date on which he has constructed works designed to regulate their fall or course, may acquire property in the waters so received. But this provision does not prohibit the owner of the source of any water, or of a pool, or a dam, from availing himself of all of the enjoyment of the waters possible within the limits of his estate.

The lower lands must receive the waters which naturally, and without the work of man, come from the upper or higher lands, as well as the stone and earth which it takes in its course, nor shall the owner of the lower land make any works which obstruct the servitude, nor the upper any works that increase the servitude. The owner of the land on which there are works to conserve the water, or on which for an alteration of the water-course it becomes necessary to construct new ones, is required, in the absence of any special law to the contrary, either to make necessary repairs or constructions, or without demanding remuneration to allow the same to be made by land owners who have experienced, or are immediately exposed to injury from the water which he has arrested in its flow, or diverted from its natural course. The provisions of the foregoing are applicable to the case in which it is necessary to relieve any land of those materials which accumulate or hinder the flow of water, resulting in damage or peril to a third party.

In distributing water among a number of claimants the following allowances are made: For a flour-mill, 8 continuous sulcos; for a pulling mill, 3 sulcos; for sugar-mills, 8 sulcos; and to irrigate a tract of land of about 33⅓ acres, 2 sulcos, or if it be a cane plantation of the same size, 4 sulcos. The quantity is, however, not absolute, but depends on the slope of the ground and other circumstances.

When the water supply is found insufficient to meet the requirements of the parties interested, resort must be had to distribution by turns, some using water in the day-time and others at night, or any other way which may be agreed upon, because that which belongs to the whole public should be so controlled that all may have a share in the distribution.

APPENDIX No. 1.

AN AUSTRALIAN REPORT ON AMERICAN IRRIGATION.

Below are presented extended extracts from a report on American irrigation to the governor of the Australian colony of Victoria, made by the Hon. Alfred Deakin, M. P., chairman of the Royal Commission on Water Supply, 1884-'85. They will be of great interest to the American reader, not only because of the author's lucid style, but because his field of investigation covers in a remarkable manner the lines of inquiry followed in collecting the materials for the foregoing report, while he presents in much detail precisely the kind of information which it has been the object of the Department to collect:

EXTENT OF AMERICAN IRRIGATION.

The extent of the area irrigated in the West is the more surprising since the practice as compared with that of Europe is a thing of yesterday. In Mexico irrigation was practiced before the Spanish conquest, and there are a few spots in its old provinces, now forming the southwestern States of the Union, where, either at the Indian villages or at the missions, plots can be seen which have been cultivated for a century by its means. In Utah Americans began irrigating in a primitive way forty years ago, and their example was followed in that fashion, especially near the Mexican border and under Mexican tutelage, for a score of years. But the real development of American irrigation, now so widespread, has taken place entirely during the last quarter of a century, and mainly during the last fifteen years. During that period it has been lifted out of its early rudeness and carelessness into something like science and skill. Its traditions date no farther than this; its records do not date so far. The strides it has taken may be judged from the now current estimate that, as against 4,500 miles of canal in Lombardy, there are 12,000 miles of main canals in the West, and that the capital invested in and about them is expressed in millions of pounds sterling.

A VIVID DESCRIPTION OF ARIDITY.

The irrigated lands of America, though widely various, may be divided into two great classes. The rolling prairies of Kansas and sloping uplands of Colorado belong to one division. Poor and brown in ordinary seasons, their buffalo and bunch grasses are often green after favorable spring rains, and it seems but natural that, when a constant supply of water is secured, these treeless expanses should be gradually conquered by the march of settlement from thickly inhabited and closely cultivated districts. Not so with the sandy wastes stretching in a broad belt from the north to the south and southwest of the arid region. Here there is no prospect of any early invasion due to pressure of population or overflow from crowded towns. Here there is nothing to attract, and everything to repel. Here even the rich red mesa lands that lie under the shadow of the foothills are desolate at all times and all seasons—so desolate that it seems impossible they should ever sustain a living thing. From them the illimitable desert, bare and blinding in its glaring barrenness, stretches far away to the mirage towers that shift along a dull and undefined horizon. Much of the soil is so powdery, even in winter, that it follows in a lazy trail of cloud the horse of the solitary rider, or is sucked up in whirlwinds under the scorching summer sun. Elsewhere its gravelly and gritty surfaces, strewn with splintered bowlders, are seamed into gaping gulches and fissures of inappeasable thirst. There is no grass, the only vegetation being a withered-looking brush resembling saltbush, the thirsty-looking cactus, a juiceless scrub like our ti-tree, or thorny variety of stunted palm.

Such is the Mapimi Desert in Mexico, the Maricopa Desert in Arizona, or the Mojave Desert in California; and such, without water, they must remain. As it is, these wastes of sandy aridity and gray innutritious herbage, surrendered by nature to solitude, surround oases created and sustained by irrigation. In the distance the track of a canal, pleasantly breaking the dull level of the dried-up plain, is marked sometimes for miles by a line of green bushes following its sinuous course. By and by this line broadens as if into a great green plantation dotted with houses, divided into gardens, and decked with flowers. Its little fields, fringed with flourishing trees, are bright with fresh-springing pasture, upon which stock are grazing, or else crowded with dark orange groves and clustering vines. In the center of it is a tiny township, busy with teams and traders, where the train stops for a moment or two. When it starts again the houses and trees vanish as if by enchantment, and the engine rushes on through the dreary desert once more.

It is thus that the eye bears testimony to the fruits of irrigation in the South; and in the North, though in a less striking way, the lesson is the same. The unpretentious ditches that wind along the hill-sides or prairie ridges are not notable themselves until it is perceived that, where they are not, a scattered herd of rough cattle, a small party of roving Indians, or a burly rancher are the only objects of interest, while, where they multiply, are the buildings, the barns, and the business. A stretch of open country broken by long ridges of canals, its paddocks plotted off into little checks, with a barefooted Chinaman or high-booted European, spade in hand, directing the water from one to the other, are common features of the landscape, where one beholds industry and intelligence transmuting barren surfaces into orchards and fields of waving grain. Familiar, too, are the knots of active men, the little camp of tents, and toiling teams, that mark the progress of a new ditch into the wilderness, where it is to create a settlement and maintain it in the face of all seasons. The Indian village, the Mexican pueblo, the American township, all cluster about the natural stream, or the artificial stream which makes it serviceable. For in these parched regions its progress is everywhere a triumphal march. It is here veritably the water of life—life to the grass and flower, to the loaded tree, to man, and to the city of men, whose homesteads and harvests follow in its wake.

HOW THE WATER SUPPLY IS PROVIDED.

In Western America the water supply is almost invariably provided by private companies. In one instance, that of Los Angeles, California, where this rule obtains, a water supply has been undertaken by the municipal body, but it is not employed for domestic purposes, being applied, curiously enough, to irrigation only. The outlay incurred is recouped by sale of the water to the farmers, a great number of whom have their plats within the city boundaries. The local governing body of Salt Lake, Utah, has also undertaken a similar work, though this is maintained out of the ordinary rates instead of by sale of water. Local governing bodies, however, do not, as a rule, go so far as this, even where, as in Los Angeles and Salt Lake, water for irrigation is as essential to the maintenance of towns as is water for drinking purposes. The utmost they do is to permit, as in Carson City, Nevada, a canal 6 feet wide to run along a main road unfenced, or, as in Phœnix, Arizona, to permit ditches 3 feet and 4 feet deep to cross their roads without requiring them to be fenced or bridged. Beyond this, municipalties do nothing. State governments have never done anything in the way of undertaking or assisting in the construction of irrigation works. They are not expected to undertake them, and there does not appear any likelihood of their ever having any proprietary connection with them. The central (General) Government maintains if possible an attitude of even greater indifference. All the irrigation works of Western America, with the exceptions above named, have been constructed and maintained wholly and solely by private persons. Not only has the Government spent nothing upon them, but it has known nothing of them. They have been constructed outside the law, extra legally if not illegally. Even now only two States and one Territory have attempted to deal legislatively with any of the problems raised, and it is not claimed that in more than one of these has anything substantial been achieved. In Colorado the State engineer has issued one report, which includes a register of water rights. In California the State engineer has issued one report specially dealing with irrigation, but there is no register of water rights. In no other State or Territory is there either report or register. These reports are of great intrinsic merit, but have a further interest, inasmuch as they are the only official papers published by any State bearing upon irrigation.

DIFFICULTIES OF THE INQUIRY.

Only the fringe of the subject having been touched officially, the visitor who desires to study irrigation finds that the data upon which he must build his conclusions are not to be obtained ready garnered in a State office, but that they are virtually uncollected, and must be sought for in the fields of practical farmers. The officials of the Central

Government and of the State governments exhibit the most considerate courtesy, but can only regret that they have been so hampered by want of means and authority that they have not been able to carry on their work in this direction, so as to place the matter upon a scientific basis. This condition of things is doubtless largely due to the newness of the country, and will tend to disappear as these regions attain to the age, population, and organization of the Eastern States. All that could be done to urge the Legislature of California to action has been done by the State engineer, who, with his colleague in Colorado, has managed at last to partially educate public opinion as to the duty of the State in this relation. But their best endeavors at present can only point to the sources in which knowledge must be looked for. The farmers of America compare favorably with those of any country in method, quickness, and caution, but they are not given to recording exact quantities of water, or the special conditions of its use, or yet the results obtained with the exactness required for professional investigation. Many of them have been their own engineers or have employed engineers who either used no plans or have mislaid them. The many lawsuits as to the use of water now pending in California naturally render capitalists who have engaged in great irrigation enterprises within its boundaries somewhat chary of giving their private records for publication. Again, partly because of the neglect of the various States to collate facts and figures relating to irrigation, each district has grown up with its own theories, prejudices, and customs, differing often to a noteworthy degree from those of its neighbors.

DIFFERENT WORKS IN DIFFERENT STATES.

The circumstances of the several States also naturally lead to great differences in their irrigation works. The mountain torrents of Colorado require to be grappled with by large and powerful weirs before they can be raised, so as to cover the high rolling uplands, while the shallow rivers of Southern California call for light structures only capable of elevating water a few feet, so as to lead it across sandy plains. Farming in the bottom lands of Arizona has led to the use of wing-dams, which can direct the flood waters of spring along the ridges, and thence command the flats beneath, and a somewhat similar class serve for the low levees of Kansas, while its bench or mesa lands (the secondary flats or table lands running up to foot-hills) call for larger ditches and stronger works, drawing their supply from the turbid Arkansas. In Utah and New Mexico we touch upon primitive works supplying small plats of land with little driblets of the precious fluid, out of which, with care and economy, thriving settlements are built up. The parent source of this system, and indeed of American irrigation, is Old Mexico, where irrigation, from the simplicity of the Egyptian water-lifter to the masonry weir and solid stone aqueduct of centuries ago, spreads its way over the whole of the territory closed in its temperate and tropic zones. If it is difficult to arrive at accurate information in the United States, in Mexico it is impossible. There is no trustworthy measurement of water, and but the lowest measure of products; a majority of those who till are too ignorant, and the minority who own the soil too indifferent to record their experience; the State does nothing to assist, and has no bureau to take cognizance of this most important factor of its chief source of wealth. Everywhere in the States or in Mexico private enterprise is supreme, and one learns only from private persons. The general condition is scanty collections of facts, and often opposite conclusions drawn from them.

IRRIGATION SYSTEM AND LAWS IN MEXICO.

Remembering the immense extent of the arid area, and the magnitude of the irrigation already undertaken in it, one cannot but be surprised at the nature of the legislation under which it has been developed. Still the omissions and mistakes made in the States furnish some valuable material. The Aztecs were experts in the art of irrigation when Cortez landed upon their shores, and the Spaniards who conquered them brought their "Law of Waters" into force in their possessions. Under the Montezumas, water was the property of the commune; under the Spaniards it become the property of the King. In both, the public interest was thus permanently recognized. Private acquisition was permitted for domestic purposes, but not for irrigation or industrial uses, except upon an authority derived from the Crown or its delegates as representing the public interest. Property in water, however, can be acquired by uncontested possession for twenty years, and is superior to property on land, since its owner has the right to carry it over any land which may lie between its source of supply and the farm to which he wishes to apply it, on payment of compensation and justification of the route. There are a great variety of enactments relating to water in the several provinces and municipal districts; but as the water available for private use has been almost all appropriated, there is now little ground for litigation as to new diversions. Public rights are jealously guarded; a land-owner near the head of a stream may not deprive a land-owner lower down of his share. Unless he can obtain an official authority, he can use no water that is not derived from springs upon his own property. The chief measures of water are the sulco, which is equivalent to a flow of 0·23 cubic feet per second; the naranja, which is one-third of a sulco; and the paja, which is equal to 0·00053 cubic feet per second. In the city of Mexico and other important municipalities the paja is the unit of measurement nominally employed. Law suits relating to the use of water are not uncommon; but nevertheless the law, with all its defects, appears to be fairly comprehended and obeyed. In what were Mexican provinces, California, Arizona, and New Mexico, the practice of irrigation was established, though on a very small scale, before their annexation to the United States, and has since developed to a considerable degree on the same lines, the only cardinal principle recognized being that of one appropriator over another in the order of priority of use, the issue of Mexican grants and the wholesale incorporation of English common law having combined to confuse the legal position of irrigation.

COLORADO AND ITS IRRIGATION LAWS.

In all matters relating to irrigation the knowledge of what is to be avoided is of equal value with the knowledge of what is worthy of imitation, and this is particularly the case in regard to irrigation law. The enactments which have proved advantageous and their particular deficiences, are both worthy of close attention. As the laws of Colorado are by far the most successful, they may be fairly allotted the first place. By the constitution of this State all streams within its boundaries were declared to be public property. By this one declaration a thousand and one sources of contention as to riparian rights were altogether closed. By special enactment it next provided for the proving and registry of every water claim. These were allowed by the courts in their order of priority, and to the amount of water which had been actually used. When these points had been adjudicated upon the claims were then published as rights. The consent of the State engineer was required before the issue of any further rights. Under a further provision the national value of irrigation was recognized as in Mexico by the granting of a general power to any person to obtain an easement for his canal over his neighbor's land upon payment of compensation. Twenty-six water districts were defined according to the natural areas of drainage and suppply, and a water-master for each was appointed, whose duty it is to decide disputes between appropriators and supervise the general distribution from a particular stream. By these simple means a host of difficulties and complexities were escaped, permanence was given to existing works, and encouragement offered for the construction of new works. It is not surprising, therefore, that in mileage of canals or acreage irrigated, Colorado more than doubles any other State, or that its works are the greatest and most permanent, and are most rapidly extending. The Territory of Utah has shown its appreciation of such results by copying as closely as convenient the legislation of Colorado. Its powerful church government has proved an invaluable administrative, judicial, and organizing agency. In California a move has been attempted, and much less achieved. In that State there is no constitutional or statutory provision that the waters shall be public property, but the common law of England has been incorporated in the civil code of the State, so far as it is not repugnant to or inconsistent with the Constitution of the United States, or the constitution or laws of this State (section 4468); as a consequence the doctrine of the right of a riparian proprietor to receive from the riparian proprietor above, and his obligations to deliver to the riparian proprietor below the water of the stream upon which his land abuts undiminished in quantity and unimpaired in quality has been revived.

CLIMATE AND IRRIGATION.

The irrigation area in America stretches from the snows of Colorado to the perpetual sunshine of Mexico, and from the shores of the Pacific to the valley of the Mississippi, embracing as great a variety of climate as is to be found in the whole of Australia. Over the whole of this great surface are scattered patches of irrigated land, and nowhere, north or south, east or west, does there appear to be any relinquishment of irrigation on account of climatic conditions. It is needless to add that, compared with the whole extent of this territory, the irrigated area is infinitesimal, but the fact stands that the high plains of Colorado, 5,000 feet above the sea, the bleak prairies of Kansas, the sandy waste of California at the sea-level, or the arid valleys of the Mexican plateau, 7,000 feet above it and within the tropical zone, are all susceptible of irrigation. The only want is want of water. Climate limits the Colorado farmer to a short season of one hundred days, while in Los Angeles or Leon cultivation is carried on all the year round. Climate determines the class of products that can be profitably raised, and temperature of course affects the quantity of water necessary to be used.

THE WATER SUPPLY.

Rainfall.—The arid area of the United States, by the terms of Major Powell's definition, includes only lands where the rainfall is under 20 inches per annum. Over the great belt in which irrigation has so far had its chief development the record for a series of years gives but little more than half that quantity, so that 10 to 12 inches may be taken as a fair average, though the extremes show a much wider variation. In Northern California and among the mountains to the east the rainfall rises to 40 inches, while in the deserts of Southern California it falls to 4 inches. In Western Kansas the fall not infrequently reaches 20 inches, but this is so irregular that the farmer who relies solely upon a natural supply loses more by the dry seasons than he can make in those which are more propitious. The question as to whether settlement increases the rainfall in the West as it has increased it in the Mississippi Valley is still undetermined, for though popular opinion is decidedly in the affirmative, the State engineer of Colorado points out that official records so far do not support the assertion. The exceptions to this are that Salt Lake, Utah, appears to be steadily gaining in depth and that dew is now observed at Greely, in Northern Colorado, a phenomenon quite unknown until irrigation had been practiced for some years. Nor does the mere amount of rainfall indicate sufficiently the necessity for an artificial supply of water unless also the seasons in which it falls are taken into account. In parts of Dakota and Minnesota, where the rainfall only averages about 20 inches, dry farming is carried on, while in districts of Texas, where the figures are as high, it would be impossible to obtain the same results without irrigation.

The explanation is that in Dakota nearly 75 per cent. of the rain falls in the season when the farmer needs it as against about 50 per cent. in Texas. Indeed a gradation may be observed in this scale from north to south, since in Kansas some 65 per cent. of the rain falls in the spring and summer, while in the extreme south, as at San Diego, only half of the whole rainfall of 9 inches falls in the spring, and is consequently useless for agriculture. There is some irrigation in Dakota, as also in Iowa and Wyoming, but not nearly so much as in the States to the southward, where even if the rainfall were as high its distribution would render it insufficient. The quantity of water needed is also affected by temperature, for the higher it reaches the more water is demanded. The loss by evaporation has not yet been determined for the several States, but it is stated that in very arid tracts it rises to over 60 inches per annum. The fact that irrigation is resorted to under such conditions should be borne in mind when we consider the wisdom of securing an artificial supply in places where the yearly fall is often sufficient.

Rivers.—That great backbone of the North American continent, the Rocky Mountains, traverses, with its companion, the Sierra Nevada, the whole of the Southwest, pouring from its snow-fields permanent streams in greater profusion than Victoria possesses. They rush from the rocky gorges out into the open country, running often bank high, and thus facilitating the diversion of their waters over the surrounding lands. But the majority of them are small, and where the supply is one peculiarity, of the utmost value in irrigation, is that they run along the ridges of the plain, while the country slopes away from their banks. In the south the rivers which supply the chief settlements are very shallow, and run in broad, sandy beds, often changing their course. The States have, as we have, streams which are a chain of pools for one half the year, and often a torrent during the other half, while with them the melting of the snow supplies the water in volumes, as in the Murray, just when it is most required.

In Colorado the San Luis and Saguache dissipate themselves in the plains, while in Southern California the Kern, in Utah the Jordan, and in Nevada the Carson, Truckee, and Humboldt terminate in lakes which have no outlet, thus furnishing parallels to the Wimmera, Richardson, and Dumnunkle of our own colony. One feature of many American streams, especially of those in sandy beds, is that they lose a great quantity of their flow by soakage, which in some cases returns to them by the same means. It has been observed of some rivers in New Mexico, as in Italy of some tributaries of the Po, that the stream tapped by a large irrigating ditch and robbed of a considerable share of its flood, regains it all again a few miles lower down. It has been found also that old river-beds still carry a flow underground, and that some running rivers have but a fraction of their streams above ground. In California sometimes as much as two-thirds of a stream has been found below its bed, and consequently what are called submerged or subsoil dams have been occasionally employed with great success, as in the Santiago Valley and at Downey, California, to arrest these escapes and bring the whole body of water to the surface. Another characteristic of American rivers is that no matter how clear the water may appear it almost invariably carries with it a sediment, which is in the majority of cases a valuable fertilizer. There are rivers, such as the King's River, California, which are said to carry no silt, and yet to fertilize the land, in which case it is to be presumed that the water acts as a solvent, disintegrating the coarser particles of the soil and preparing the fertilizing elements for absorption in plant growth.

The topography of this State, California, has been especially favorable to small schemes, and has induced the farmer, by its opportunities of obtaining water when he most needs it at a minimum of labor and expense, to commence experiments on his own land.

Springs and wells.—In the matter of the supply obtained from underground, American experience is, on the whole, encouraging. In the Los Angeles and San Bernardino Counties, California, there are springs or springy marshes called cienagas which irrigate from 20 to 400 acres each, and together supply an area of 7,000 acres of cultivated lands. Such springs are an important source of supply in Italy, where they are styled fontanili. Here some are so charged with mineral matter as to be unfit for use and have usually so small a flow as to be employed for orchard irrigation only. At San Gabriel, California, a vineyard 1,200 acres in extent is supplied solely by springs or artesian wells, of which there are twenty-one on the estate, ranging from 75 to 100 feet deep. In Southern California, altogether there are calculated to be one thousand of these wells, varying in depth from 200 to 550 feet; some of them have a flow of 1.7 cubic feet per second, and suffice for the irrigation of small farms.. On one estate there are fifteen of an average depth of 200 feet, yielding water at the rate of 2.2 cubic feet per second. Artesian water has been, if anything, rather dearer than canal water in California, but has the advantage of being at a higher temperature than snow-fed streams.

In Santa Clara County, California, there is an artesian tract yielding 2,000,000 gallons every twenty-four hours, but the greatest supply from such sources is at Denver, Colorado, where a stream of 2,880,000 gallons per day is derived from eighty wells, which range from 300 feet to 900 feet deep. In sinking these the "club-churn" drills have been found cheaper and quicker than the diamond drill, sinking 45 feet in twelve hours, as against 15 feet with the diamond drill, or 90 feet in twenty-four hours, as against 35 feet. When artesian water is used the wells are, where possible, put down upon the highest part of the farm from which the water can be most easily distributed; when the water is raised by means of a windmill from an ordinary well, which is usually upon low ground, it is delivered into a light wooden flume, which conveys it into a reservoir on some commanding spot. In California, and especially at Florin, water is raised from depths of 10 to 20 feet in a steady stream by means of windmills, one of which, as a rule, can supply 2 to 3 acres of land with water. Further south the water is raised from more than twice this depth by the same means. In most cases the water is bored for and struck, but does not rise to the surface, the windmill being employed to lift it the extra distance. If water were found without boring at 10 feet deep, irrigation for vines or lucern would be considered surperfluous. The utilization of such small quantities of water as can be obtained by these means attests the value set upon any supply, however minute. Though the streams of the West are considerable in number, they are small and far between in almost every district in which irrigation is necessary. There are most extensive areas without appreciable rainfall, without rivers, and without springs. The irrigable area is narrow and widely distributed, occurring, except in Colorado and Kansas, in comparatively small allotments.

IRRIGATION WORKS AND THEIR CONSTRUCTION.

It is next desirable to consider the means by which water is diverted and the methods of its application so as to share any knowledge which Americans possess in these directions. To comprehend the nature of their works it is desirable to bear in mind their history, for they have rarely been the result of one foreseen plan, but have, as a rule, been brought into their present condition piecemeal. It must be remembered that they are not State works, and that in many cases they were not constructed by companies or capitalists, but by the farmers themselves, either singly or banded together. On the faith, perhaps, of a good season the settler had taken up land and after his crop was in had seen himself in danger of losing it, or else in sheer desperation he had settled without expecting a rainfall and determined to try the Mexican custom of flooding his fields. In either case his necessity has been the same. He must have water or be ruined. If it did not fall from the clouds he has asked himself why it should not prove as efficient if obtained from the nearest stream. With this pressure upon him he has not waited to inquire into his legal rights or seek for engineering skill or hold public meetings. He has hitched his team and with plow and spade run a rough ditch to the river bank. By cutting this through, and if necessary throwing up a slight wing-dam to turn the water in, he has been able to soak his fields, save his crop, and probably get half as much again as an ordinary yield. Stirred by this gain, and by a strong sense of successful self-reliance, he has made his work permanent. A neighbor has joined him in enlarging the ditch, and then shared in its benefits. Others have been encouraged to face the same task. Where several were interested they have joined their forces, apportioned the work, and each carried out his share or paid for its being carried out for him. By these means a great number of so-called works have been constructed, and, learning from them, the small capitalist and the large capitalist have followed suit and have built canals to supply water for use upon their own lands or upon lands which they wish to let or sell, or upon the lands of others to whom they intend to dispose of the water they have secured.

These works have been built often without engineers, almost always without plans, and their defects are patent. The weir head-gate or wing-dam, as the case may be, has been carried away several times, and has probably cost more to replace than a substantial structure might have cost. Then the easiest courses for the ditches have been chosen, so that, instead of running on high land, they have even followed old water-courses, and thus have commanded from the canal a much smaller area and more imperfectly than they should have done. There have sometimes been no surveys, and as a consequence curves have been too sharp and grades too steep, so that ditches gradually destroy themselves, cutting out their own banks and filling in their beds. Or, perhaps, an opposite fault has been committed, and there has not been current enough to keep down the water weeds which spring up in the channel and choke it.

Then, again, the natural result of individual effort of this kind has been that several canals have been built where only one was necessary. For instance, there are five ditches supplying the Mussel Slough district, California, where one would carry all the water with far less loss in the carriage. There are thirty-two canals taken out of the Kern River, where eight would have been abundant; and at Fresno half a dozen where two would have sufficed. What loss this involves may be estimated from a calculation of the State engineer, who, after a careful examination of two of these canals, finds that their combined stream could have been carried in one channel at a saving of 20 per cent. of the water conveyed. The engineering defects of such works are palpable, and are not disputed or disguised. At the same time it would be a mistake to condemn them out of hand. At least they have served their purpose for a time—it may be wastefully, but the waste could not have been prevented. Crop after crop has been saved—the farmer has kept his land, has built his house, and cultivated his plot comfortably by their means. If he now possesses the knowledge needed to irrigate and build ditches, and has the money in his pocket to enable him to use his knowledge, he owes it all to these first rude efforts of his by which he put the water upon his fields cheaply and without delay.

Everywhere, however, engineering work is characterized by extreme simplicity and economy; it is rarely massive and never ornamental. There is no attempt at finish, but only at efficiency. Water-works in the West are like railways, often made to pay for their own construction. At first just enough work is done to enable them to yield a return, and then additions are made from time to time, until at last they are brought into a condition of stability. In places where it is cheaper to build a new weir or wing-dam of brush and sand every year than to pay interest upon the sum required for a permanent structure the temporary work is invariably resorted to.

It is rare also that any work is built strongly enough to endure all contingencies. The practice is to put up a weir that will stand in ordinary seasons, foreseeing that it will be swept away by the first of the heavy floods which occur periodically every few years.

There are many ingenious engineering devices for decreasing expenses, but this principle of risk to save interest governs all. American engineers know that these works are not permanent when they build them. As a rule they have the professional dislike of building temporary works, and, not having to provide the funds, prefer structures that will prove a lasting credit to them; but shrewd capitalists have tested the principle in practice, and they find it pays to resort in many cases to these slighter works.

SOME OF THE PRINCIPAL WORKS.

Among the illustrations of this combination of risk with very clever engineering there are none better than those to be found at Bakersfield, where Mr. James, as engineer for Messrs. Haggin and Carr, has had a large field for the display of his ability. Timber is cheap in America, and California is favored with the redwood, which is soft, easily worked, and yet durable; consequently it is almost wholly employed by Mr. James upon his 250 miles of canal. His main gates cost from £40 to £60, while his head-gates, controlling a flow of 30 feet or 40 feet of water 3 or 4 feet deep, are erected for £6C0. A wooden weir in the Callaway Canal, costing only £2,600, is 700 feet long, can be put in place in a couple of hours, and is ingeniously arranged so that its superstructure is rapidly removable. Many of the contrivances employed on these ranches are well worthy of imitation wherever shallow streams are to be dealt with in a level country. The combination of weir and bridge in the same wooden structure is another feature of these works well worth the attention of local governing bodies, one of these, 360 feet long, 20 feet wide, raising the water 5 feet, and reckoned to have a life of at least twenty years, being built for less than £2,000.

In the streams of Southern California, which are of no great depth as a rule, brushwork is generally used for weirs and dams, sometimes being loaded with sand-boxes or sand-bags or protected with fascines, loaded down with cobble-stones. Thus the San Joaquin and King's River Canal, California, has such a wing-dam, 350 feet long, as has the Larimer and Weld Canal, Colorado, where the dam is 177 feet long and 5 feet 8 inches high. Examples of this class of construction on a great scale, though not for irrigation, may be found in the Yuba and Bear Rivers, where two dams may be seen, one of them 8,900 feet long, and the other 5,875 feet long, ranging from 3 feet to 15 feet in height, and from 60 feet to 120 feet in width. Perhaps the largest irrigation head-work in this style is that of the Eureka Canal, in Kansas, which is 1,500 feet long and 8 feet high, supported by a dyke a mile long on the south side of the river, and diverting 5 feet of water through a cut in the banks of the Arkansas, 16 feet deep, into a canal 28 feet broad at the bed and 80 miles in length. The dimensions of these works, together with the stability of such head-gates as that upon the 76 canal, Fresno, California, which is also a bridge of 100 feet long and 20 feet wide, and raises the water 5 feet at a cost of £1,000, and the ingenuity of the head-gate of the Chowchilla Canal, resting upon a quicksand, as described in the engineer's report, are evidence enough of the ability which is displayed in many works. In Northern California there are both dams and weirs, of great height and excellent simplicity of structure, erected for mining purposes, and now, in a few cases and on a small scale, utilized for irrigation as well as motive power. For the most substantial of all head-works, however, we must look to Colorado.

There are some small stone-weirs in the South, and some fine pieces of masonry work of great antiquity in Mexico, but none of these are liable to such enormous strain as is met with in the wild cañons of the Rocky Mountains. The South Platte Weir, for instance, is 120 feet long from the cliff on the one side to its waste-gate of solid masonry, 24 feet wide, on the other, raising the water 14 feet by means of a frame-work of 12 by 12 timbers bolted into the bed-rock, filled with stones and planked on the face with six-inch boards. The apron extends 54 feet up stream and 18 feet below the weir, the water having a perpendicular fall. The waste-gate and off-take are both protected by substantial "booms" or "grids," the latter 72 feet long, built of 12 by 12 timbers. These admit the water through bars below the surface and protect the work from the trunks of trees, which are carried down with great force when the stream is high. These "booms" are in frequent use in Colorado, and are worthy of note for application upon the many Australian streams in which heavy floods invariably whirl along with them great quantities of timber with a force that would destroy an unprotected structure as speedily as a battering-ram. The weir across the North Poudre endures even fiercer floods, and is more massive in structure, stretching 160 feet across a rugged cañon, from wall to wall in the form of an arch, bending up stream, and composed of strong cribs filled with stones; it raises the water 26 feet into its flumes. The lower face consists of three steps pitched with stones, which are so keyed in each other that the pressure upon them only serves to wedge them more firmly in. As it has stood two or three severe floods without sustaining any damage it may be considered a success, more especially as though situated in an out-of-the-way district over 20 miles from the nearest station, and a mile up an almost inaccessible gorge, its cost was less than £2,000. It was considered worthy of being made the chief subject of a special paper read before the Institution of Civil Engineers in London.

Enough has been said here to indicate the character of the chief classes of head-works, of which there are a great variety in each State. The minor works, such as drops, gates, or regulators, are usually of wood, and of simple design. In the South Platte Canal a much superior gate may be seen, the off-take from the main canal being by means of an earthenware pipe set in stones, beyond which is the usual gate and a measuring weir. The head-gates, however, include but a small part of the works undertaken in order to secure a supply of water. There is a prevalent idea that in America the streams only require to be touched with a spade to pour themselves upon the farmers' sown lands. That such is not always the case in Colorado may be seen from the fact that the South Platte Weir referred to above, built at a cost of £4,000, serves to raise the water to the level of a tunnel 600 long, 20 feet wide, and 12 feet high, hewn through the solid rock, at an outlay of £12,000, emptying its tide into a wooden flume 2,640 feet long, 28 feet wide, and 7 feet deep, which cost nearly £20,000, and is supplemented further on by other wooden flumes along the 83 miles for which this artificial river has been excavated across the plains. The North Poudre Canal has about a mile of wooden flumes, and three tunnels, one of them 900 feet long, necessitating an outlay of £10,000 for its first mile before it touches the open country, through which it flows for 50 miles. Nor is expenditure of this character limited to great canals supplying large areas. The price that can be paid for water may be better understood by noting what the outlay is upon small areas.

At Pasadena, where there are but 1,500 acres to supply, the water is carried from the weir by a flume 700 feet long into an iron pipe 3 miles long, from 13 inches to 11 inches in diameter, to a reservoir with a capacity of 3,000,000 gallons, partly rock-walled and partly cemented. From this another iron pipe conveys it to the land to be irrigated, while a lower portion is supplied from another source by a pump throwing 30,000 gallons an hour into another 500,000-gallon reservoir, from which it is distributed by a mile and a half more of iron piping. The total cost of these works is given as £8,000. The Lake Vineyard Company to the east have a concrete ditch 17,000 feet long and a quantity of iron piping simply to water their own vines. The supply to the neighboring colony of Anaheim is carried in a flume 6,970 feet in length. At Redlands there are 6 miles of iron piping 1 foot in diameter, carrying 5 cubic feet of water per second from the weir to the 2,400 acres which it is intended to irrigate, upon which there are stand-pipes and iron measuring weirs to every allotment. At Ontario, with its 8,000 acres, the arrangements are equally perfect, a large portion of its supply being obtained by a tunnel nearly 3,000 feet long, upon which £10,000 have been spent. An illustration of another class of water-works on a great scale may be seen among the mountains of Nevada, where there are wooden flumes from 50 to 80 miles in length, down which sawn timber is floated from the forests among the hills. The distance which great streams of water have to be carried before they can be utilized may be judged from a few illustrations.

The Dodge City Canal, Kansas, is 90 miles long and 50 feet wide; the San Joaquin and King's River Canal, California, 78 miles long and 68 feet wide; the South Platte, Colorado, is to stretch 160 miles when completed; while the Great Eastern, Kansas; the 76 Canal, Fresno, California; the Larimer and Weld, Colorado; the Arizona Canal, Arizona, all range from 40 to 60 miles in length, with a breadth of over 30 feet. In considering the length of these canals, it should be remembered that some of them have been carried much farther than the natural circumstances required, passing irrigable lands in their course just as rich as those they reach beyond, but which are unsupplied because they do not belong to the proprietor of the ditch. The area of irrigable land under canals of these dimensions amounts often to from 50,000 acres to 250,000 acres each, but from none as yet is more than the smaller quantity under cultivation. In Utah, settlements have been abandoned because they were located too far from the streams supplying them. The higher up stream an off-take of a canal is, and the shorter the distance water is carried to land, the less the loss by soakage. The more favorably situated flats, however, usually lie farther down stream, and as these are always the first to be irrigated it becomes necessary for the later settler to take up higher ground, to water which he must go farther up the river. There is thus a tendency for the canals to become longer as the country is taken up. It is unnecessary to describe their construction, for they are merely ditches of sizes and grades varying according to the soil in which they are cut and the water they have to carry, which is from 1 cubic foot to 2,000 cubic feet per second. The average cost of a 30-foot canal is reckoned in ordinary country at from £200 to £300 per mile by Colorado engineers. The average grades chosen are from 1 to 3 feet per mile; the banks, in most places, being on the slope of 4 or 5 to 1. The breadth is adjusted so as to equalize the discharge, being greatest where the grade is least.

The amount of money which private persons have invested in these works shows that the prospects of profit are tempting. The San Joaquin Canal represents in direct and indirect outlay £260,000; the Dodge City, £160,000; the South Platte, £150,000; the Arizona, £100,000; the North Poudre, £50,000, and the City Ditch, at Salt Lake, £45,000. Several of these are built by companies which have other canals of considerable size and land purchases made in connection with them, in which even larger sums are sunk. Two companies in Colorado control between them nearly 500 miles of main canals, which together with the land they were constructed to water, represent an outlay of more than half a million sterling. As far as can be judged there are no apprehensions entertained as to the future of such investments; their proprietors appear satisfied with their returns up to the present time, and not unwilling to enter upon extensions of their existing enterprises. Still the figures, even now, should make it plain that irrigation in America is not the simple matter it has been supposed, but one that taxes the capital and enterprise of even a speculative people.

THE PRINCIPAL IRRIGATION RESERVOIRS.

Next to headworks, the most important feature is the provision of storage, by means of which the surplus of winter rains or spring floods may be retained for use in time of need. The surveys made in California and Colorado so far have discovered many natural depressions of no great extent, but still valuable in connection with irrigation schemes. In Los Angeles County are to be found a number of reservoirs already built, some of them cemented; others, such as those of the Lake Vineyard Association, composed of the natural soil. Most of these are small, the largest containing 21,000,000 gallons. The cost of excavation here was from 7*s.* 6*d.* to 12*s.* 6*d.* per thousand cubic feet of storage. In New Mexico, by means of a series of earthen dams, one farmer has created seven reservoirs, from which he can command, with a reserve supply, some 2,000 acres of his estate. In Colorado the mountainous character of the country has been favorable to the construction of similar works, the State engineer recording a number of them at 6 feet to 35 feet deep and 10 acres to 500 acres in extent. The largest is that in connection with the Big Thompson Canal, which covers 427.35 acres to a depth of 35.8 feet, of which 21.8 feet is available, and is expected to water 12,000 acres. A chain of such reservoirs is being added to the North Poudre works previously referred to. But by far the greatest of these reservoirs is situated in the Bear Valley above Riverside and Redlands, Calaifornia, where, by means of a wall of masonry 300 feet long and 60 feet high, 8,000,000,000 gallons, or more than the contents of the Yan Yean when full, are preserved, owing to exceptional natural advantages, at a cost of £12,000. This will give a continuous stream of 150 cubic feet per second for 100 days, which, on the scale of supply adopted at Redlands, should water at least 50,000 acres. A still larger reservoir is projected in Southeastern Colorado, where water sufficient to supply 100,000 acres is to be stored, in connection with a canal 80 feet wide, 7 feet deep, and capable, with the reservoir, of irrigating twice that area.

CONSTRUCTION IMPLEMENTS.

The implements themselves are various, and a considerable portion of the saving is made in the knowledge when to use one and when to replace it by another. To begin with the simplest kind of construction, that of field ditching, the farmer does this, as a rule, with his plow, with which he can easily run a ditch of a few inches capacity across the field. If he intends to widen it while keeping it shallow he employs the ditch plow, which consists of a blade suspended behind the share so as to push the earth, which it cuts to one side. In many soils this is found to be an invaluable implement. When the work is more roughly done, what is known as a V scraper is brought into play. This varies from a mere log of wood with a couple of old spade heads nailed in front, forming a sharp prow, which is its rudest form, to a triangle some 6 feet wide at its wooden base, from which proceed two long iron blades forming the acute angle. Its use is always the same. It is drawn by horses and steadied by the driver's weight, so as to push the earth outward from a simple plow furrow or series of furrows, and thus form a ditch. When this is over 6 feet in width a "side-wiper" is generally substituted, which is a long iron blade, lowered from a frame which rests upon four wheels, so that when drawn by a powerful team it slants the plowed soil to one side. In light soils and for large ditches an elaborate machine is used, which not only plows the earth but takes it up and shoots it out upon the banks, a distance of 10 or 12 feet, to either side, at the rate of from 600 to 1,000 cubic yards per day.

But the implement most in use for operations of any extent is the iron "scraper," which is found in many forms, sometimes runs sledgewise, sometimes upon wheels, and ingeniously fitted so as to be tilted without effort. For a long pull wheels are considered best, and for steep banks runners have the preference, but scoops are preferred without either for sandy soil. The kind of soil to be moved and worked upon and the length of haul are always taken into account in determining the class of scoop used. In constructing a deep canal a haul of 1 foot upward is reckoned the equivalent of 50 feet on the level, and with an experienced driver and a team of two horses or mules a scoop is expected to remove from 80 to 120 yards per day. Sometimes in railway work one man is told off to every four teams to fill the scoops, but in the majority of cases the driver does this himself. There is another implement known as the buck scraper, which for ordinary farming use in light soils and in practiced hands accomplishes remarkable results. It consists of a strong piece of 2-inch timber, from 6 feet to 9 feet long and 1 foot 3 inches high, with a 6-inch steel plate along its face projecting 2 inches below its lower edge, and is strengthened with cross-pieces at the back, where there is a projecting arm, upon which the driver stands. Like the ordinary scraper, it is also found on wheels and runners and in many patterns, and is drawn by a pair of horses. Instead of taking up the earth as the scoop does, it pushes the soil before it, and when under good command does such work as check-making, ditch excavating, or field leveling, in sandy soils, with marvelous rapidity. Work with the scoop costs, as a rule, from 4*d.* to 6*d.* per cubic yard; when the cost reaches 9*d.* it is considered time to set it aside.

With the buck scraper work has been done in favorable localities as low as 2*d*, and even a penny, per cubic yard; and it is astonishing to note the number of uses to which this simple implement is successfully applied. Where the leveling of fields is difficult a machine is sometimes used which cuts off the tops of mounds or ridges and drops the stuff in the first hollow over which it passes. The windmills for raising water from wells have been already alluded to as have the boring machines at Denver. Where the water is to be raised from a running stream a wheel is employed turned by the current, raising little bucketsful and pouring them into a wooden flume from 12 feet to 20 feet high. Many little contrivances, such as a movable iron gate or "Tapon," for diverting water at any point from field ditches, and shaped like a railway disk, are to be met with.

DISTRIBUTION BY PIPES.

In this connection it may be well to notice the variety of pipes employed for water supply and likely to be more employed as water becomes scarcer and fruit-raising increases. Where suitable material is at hand it is not uncommon to find ditches, as at Lugonia, California, roughly paved for 6 or 7 miles, thus saving one-third of the water previously lost in this distance. Again, the South Fork ditch, from the Santa Ana, is made in a similar way, by neatly-fitting cobblestones together, and with an equally satisfactory result. Near Pasadena, as already mentioned, there is a concrete ditch more than 5 miles in length. This mode of ditching, however, is not always possible, and, where such an outlay can be faced, it is generally advisable to use pipes. The greater profits realized from fruit-growing encourage such an expenditure, by means of which a very small stream can be made to cover a comparatively large area.

Pipes can either be employed to bring water to land upon which it is to be used or they can also be carried on so as to distribute the supply throughout the cultivated area. This latter process, known as subirrigation, will be described at a later stage. When it is practiced a simple machine is generally used, by means of which a cement pipe is made in the ground and in position, thus saving the risk of transportation and some cost of labor. The scale on which this has been attempted is not as yet sufficient to demonstrate its universal efficiency. For main channels a concrete pipe, cheaper than earthenware piping, is largely in use in the "colonies" of Southern California, as at Ontario and Pasadena, where it has proved durable and serviceable under low pressure. In the San Demas Cañon there are 3 miles of this pipe, 5 inches in interior diameter, carried along the face of a cliff. Its most formidable rivals have been a riveted and asphalted pipe and a light laminated pipe, both of wrought iron, the latter made by telescoping one sheet-iron pipe into another, when submerged in asphalt and tar, and thus filling up the small space between them with the mixture. As a 4-inch pipe of this pattern is supplied for practically the same price as that in cement, and has proved itself capable of withstanding great pressure, the preference, on the whole, appears to be given to the iron. Where it is found, as in Utah, that a ditch, 3 feet deep, which is 20 feet wide for the first 23 miles of its course, can in the next 2 miles carry all that is left of its stream in a width of 12 feet, it becomes plain that where water is valuable there is a fair margin to pay for piping.

METHODS OF IRRIGATION.

Flooding.—The earliest, easiest, simplest, and cheapest method of irrigation is by flooding. The water is then directed so as to cover the whole area under cultivation to a depth varying according to the crop and the quality of the soil. This plan is the most wasteful of water, but cannot be avoided in the cultivation of cereals. The only work it involves in the field is that necessary to permit an even flow of water. With a regular slope this work is sometimes trifling, but as a rule some preliminary outlay is required for leveling inequalities, or else providing for the equal distribution of the stream from points of vantage. When the fall is slight, shallow ditches are run in Colorado from 50 feet to 100 feet apart in the direction of the fall; when the land is steeper they are carried diagonally to the slope, or are made to wind around it, and from these, by throwing up little dams from point to point, the whole field is inexpensively flooded. When the fall is still greater and the surface irregular ridges are thrown up along the contour lines of the land, marking it off into plots called "checks," on the whole of the interior of which water will readily and rapidly reach an equal depth. When one plot is covered the check is broken and the water admitted so as in the same way to cover the next plot.

The ridges or "levees" must have rounded crests and easy slopes, or else they interfere with the use of farming machinery, such as the stripper. By means of diagonal furrows and checks remarkable results are obtained, even in very broken country. By their means it is claimed that in Colorado one man can irrigate 25 acres per day. Where checks have not been used upon ground with an acute incline, the water has soon worn deep channels through it, utterly ruining it for agricultural purposes; or again, where the water has been allowed to flow too freely the consequence has been that all the fertilizing elements of the soil have been washed away. In flooding the aim is, therefore, to put no more water upon the land than it will at once and equally absorb or can part with without creating a current sufficient to carry off sediment. The neglect of these precautions has caused the abandonment of several settlements made in Utah before the art of irrigation was properly understood.

In Southern California checks are employed even more successfully than in Colorado, the levees being built by buckscrapers, so as to prepare large areas for crop at 2*d*. per cubic yard of material moved, or 6*s*. per acre.

The lands there are not so rolling as in the northern uplands, where the average cost of preparing land for irrigation is from 8*s*. to 16*s*. per acre. As much higher estimates have been given in Victoria, it should be noted that the higher price is for country more difficult than the average of our northern plains. It would be possible, by grading and terracing, to water very steep slopes, but the labor would not be paid for by any cereals that could be raised. Both the depth and number of floodings are varied according to soil and crop. With a clay soil the waterings are light and frequent, while with a sandier quality they are heavier and rarer. Much, too, depends upon the distance and nature of the subsoil. There is considerable uncertainty with regard to the measurements given for flooding. It is sometimes placed as low as will give a depth of 2 or 3 inches, and at other times as high as from 5 inches to 10 inches at a single watering. There are cases in which as many feet have been used. The number of waterings is best determined by the crop itself, and the most skillful irrigators are those who study its needs and take care to supply them without giving an excess of water. The quantity used alters, therefore, from season to season, so that only an average can be given.

In Colorado, where water is used more lavishly than in any other State, some good judges have agreed that an average of 14 inches should be ample, and this is certainly not too low. Where the soil is liable to become hard, and will retain moisture, wheat is often grown with two floodings, one before the ground is ploughed, and the other when it is approaching the ear. When two waterings are given after sowing, one is when the wheat commences to "tiller," and the other when it reaches the milky stage. Where irrigation does not precede the ploughing, it is postponed as long after the appearance ot the crop as possible. Sometimes wheat has three, or even as many as four, floodings; but this is unusual, as overwatering occasions "rust." Experience shows that it is easy to exceed the quantity required by the crop, and that every excess is injurious. Extravagance is the common fault, so much so that the most successful irrigators are invariably those who use the least water. The less water, indeed, with which grain can be brought to maturity, the finer the yield.

Furrows.—Peas and potatoes are not irrigated by flooding, but from furrows 4 feet to 10 feet apart, and this is found the more economical and more successsul system for vines and fruit trees.

Under the flooding system, the ground, if not protected from the sun, cakes quickly. When the water is run down furrows drawn by a plough between the plants, this caking is avoided, and the water soaks quietly to the roots. When flooding was practiced in orchards it was found to bring the roots to the surface and enfeeble the trees, so that they needed frequent waterings. Sometimes the furrows feed a small hole at the foot of the tree, from which the water soaks slowly in. When this is done mulching is found desirable over the hole to reduce the loss by evaporation. The general rule is to protect the trees by small ridges, so that the water does not affect the surface within 3 or 4 feet of them. The simple furrow, however, is most generally in use. Oranges are watered three or at most four times in summer; vines once, twice, or often not at all after the first year or two; and other fruits, according to the caprice of the owner, the necessities of the season, and the nature of the soil, one to four times. It is impossible to be more exact. An even greater difference, comparatively, in the quantity of water used obtains in the furrow irrigation of fruit trees and vines than has been noted in regard to cereals. To such an extent does this prevail, that not only do districts differ, but, of two neighbors who cultivate the same fruits in contiguous orchards, having exactly the same slope and soil, one will use twice or thrice as much water as the other. Judging as far as possible from conflicting testimonies, the cardinal principle appears to be just the same. To attain the best results the trees must be carefully watched, and supplied with only just enough water to keep them in a vigorously healthy condition.

Another all-important principle, as to which there is no question, and which is testified to on every hand, is that the more thoroughly the soil is cultivated, the less water it demands—a truth based partly, no doubt, upon the fact that the evaporation from hard, unbroken soil is more rapid than from tilled ground, which retains the more thoroughly distributed moisture for a longer period. For the irrigation of cereals, works are required on a larger scale proportionately than for fruit; because in the first case the water is demanded in greater quantities at particular times, while in the latter the supply can be more evenly distributed throughout the year, though of course the irrigating season with both is much the same. In the Northern States irrigation is limited to a hundred days, while in the South it can be employed at discretion all the year round. In both regions winter and autumn irrigations are growing steadily in favor. Land which receives its soaking then needs less in summer, and is found in better condition for plowing. It is argued that moisture is more naturally absorbed in that season and with greater benefit. Everywhere the verdict of the experienced is that too much water is being used, and the outcry against over saturation in summer is but one of its forms.

Sub-irrigation.—Irrigation beneath the surface, if not excessive, is considered the most perfect method of supplying water to vegetable life, and it has been the aim of many to devise a scheme by which this can be done with the greatest economy. The idea is to replace soakage from above, by either flooding or furrows, with what is called "seepage," that is, subterranean and lateral soakage which, to be perfect, should not wet the surface. The one advantage possessed by surface over sub-irrigation is that, when carefully managed, irrigation by soakage is a perennial source of fertilization on account of the quantity of deposit which is obtained with the water from most streams in certain seasons. Irrigation by seepage cannot produce this beneficial effect, but it can avoid the dangers of excessive saturation or surface caking, or of washing out the richer elements of the soil, aswell as accomplish an enormous saving in the water used. Two difficulties have presented themselves to its complete success. The first of these is the tendency of the apertures in the pipes to become choked by the roots, which tend to form a mat about it. The main difficulty, however, so far rather feared than experienced, is that the constant seepage of water would have such a solidifying effect upon the soil, closing its pores and converting it into an almost impenetrable mass, that it would become necessary after some years to break it up to a considerable depth by cultivation. Of this it is too early to pronounce, but it certainly appears that sub-irrigation is the hope of most intelligent irrigators, because it promises a great economy of water, and the most direct application of it to the thirsty tree that it is possible to devise. The average cost of making and laying pipes for sub-irrigation is given by an authority at £7 per acre, a sum which the owners of land under intense culture could afford to pay.

Open ditches are wasteful.—The present practice is the most wasteful that could be devised. There is waste along all the miles of open canals, both main and secondary, with a consequent loss to the owners of from 25 per cent. to 50 per cent. of the stream they take in. Sometimes it is even greater; a canal in the San Joaquin Valley, which took in 90 cubic feet per second at its head, only delivering 14 cubic feet per second on the farms 28 miles away. Where the canal owner's loss ends, that of the farmer begins. He loses all along his laterals tapping the secondary canal, all along his sub-laterals intersecting his farm, and, again, all that is not absorbed by the crop over which he pours his periodic flood; besides which has to be added the loss from evaporation. As a matter of fact, therefore, he only receives the benefit of a very small proportion of what he pays for. Some put the loss of farmer and canal proprietor together as high as nine-tenths of the water diverted, others at three-fourths, and it is rarely calculated at less than the latter figure. There is certainly ample room for saving at every turn. In Utah, as in Italy, another economy is effected by requiring those entitled to water to take it at night as well as by day, so that, instead of the supply running to waste for eight to ten hours out of the twenty-four, the whole capacity of the ditch is utilized every minute during the irrigating season. This custom has the further advantage that the water is thought to act more favorably upon the soil by night than if it were under the burning rays of the sun. The manual labor or skill required for controlling water is not great, and it calls for patience and attention rather than activity. To see the irrigator, spade in hand, engaged, in a leisurely way, directing the stream gushing from his ditch, it would scarcely be suspected that upon so unimpressive a proceeding the whole future of the orchard in which he is engaged entirely depended. There seems an incompatibility between causes and effects which asserts itself in many ways, so that it becomes an effort to realize that the rude ditches which wind their rugged banks across trim fields, or among regular rows of vines or orange-trees, are actually the generous source from which all the profusion of foliage and fruit is being invisibly fed.

FERTILIZATION BY IRRIGATION.

Part of this incompatibility no doubt arises from the fact that there is something more than water conveyed in canals, and that this something more is extremely valuable, though usually left out of the calculation. Water of itself can work wonders, but when allied with sediment, which in nine cases out of ten appears to consist either of decayed vegetable matter or to contain elements that replenish the soils by which it is absorbed, the results become multiplied. In France the practice of pouring large bodies of water heavily charged with sediment upon inferior lands for the purpose of reclaiming and enriching them is extensively adopted. This is not systematically attempted to the same extent in America, though the sandy sage-brush lands of Utah and Nevada have been turned into rich meadows in the same way; but it is generally recognized that where irrigation is so controlled as to admit of just as much water being placed upon the land as it can drink at a draught, without allowing it either to stand or run away, then the consequence is invariably a maintained or an increased production. Not only is the crop secured, but whether it be grain, root crop, or fruit, the yield is often largely enhanced so as to reach, in arid regions or upon poor soils, a yield equal to that obtained upon fertile lands enjoying a plentiful rainfall. Farmers' estimates of what this gain actually is differ considerably, ranging from 30 to 100 per cent. That there is a gain, and a great gain in many instances, no one thinks of disputing, though there may be some looseness in the figures quoted concerning it. There seem to be no products of which the crop may not be increased by irrigation, and there are none that will not suffer from over-irrigation. The richest silty water, instead of having a fertilizing influence, will be fatal if allowed either to stagnate or to rush too rapidly through a field. But with this danger provided against irrigation may mean fertilization to such an extent as to render any further artificial enrichment of the soil unnecessary. In most parts of the West this has been the only fertilization which has maintained land under years of cropping.

IRRIGATION DRAINAGE.

As a matter of fact there are no drainage works worthy of the name in America, the farmer having quietly left the water to settle this problem for itself. Water is always valuable in these regions, and what one farmer allows to flow by another is only too eager to acquire. Canal proprietors have not found any necessity to spend money in making provision for the surplus water which passes their area of supply, as it is generally extremely easy to let it find its way into the natural water-courses which run at lower levels than the artificial stream. How to get water is the one question of importance; how to get rid of it has been found in nineteen cases out of twenty only too easy. With a deep subsoil or a good fall it seems as if drainage may always be unnecessary, and these are conditions very frequently met with. There are, however, lands comparatively level in which sooner or later it will be required, and there are one or two localities in which the need of drainage works is rapidly becoming an imperative necessity. Among these by far the most striking illustration is furnished at Fresno, Cal., a district in which the same facts are also extremely valuable as indicating the change in character of an arid plain submitted to years of extravagant irrigation. Fifteen years ago its sandy soil, sparsely covered by struggling herbage, grassless and treeless for scores of square miles, maintained only a few herds of cattle. There was no sign of cultivation within its borders, water could only be obtained by sinking from 40 feet to 80 feet, and the rainfall was both irregular and insufficient. The King River, which was its one available stream, sometimes carried no more than 500 cubic feet per second, and when the first "colony" was established it was stoutly maintained that the whole of its waters would not suffice to supply this little plot marked out in the midst of the wild.

For some time—indeed even after the canal to supply this colony had been constructed—so rapidly did the open ditch absorb the intake that it was thought that the water would never reach the settlement at all. Week by week the tiny thread of fluid trickled and wound its way along; at last it entered the fields prepared for it, and, the flow steadily strengthening, crept farther and farther on, feeding an ever-widening district, until today there are fifteen canals drawing their waters from this river, irrigating 55,000 acres of land, which form a chain of settlement all around the Central Californian colony, and extending 16 miles beyond it. Water can now be struck anywhere across the whole plain at 10 feet, and often at 6 feet. The seepage from the canals has been great indeed, for it seems to have filled the whole subsoil, which has sucked it up like a sponge until it can hold no more. One important consequence is that irrigation by flooding or furrows is being abandoned at Fresno, as the irrigation by seepage maintains a constant supply within easy reach of the roots of vines and trees.

The once arid region has become thoroughly moistened. Where till lately the contention for water was keen and ceaseless, one hears now of suits against canals on account of their supersaturation of adjoining vineyards. Nor is this to be wondered at, seeing that, in the midst of the once parched plain, there are now patches of artificial morass created, as in the Poudre Valley, Colorado, by over-irrigation, and continued for want of drainage. For in Fresno, and Fresno alone, has drainage become a vital question. The largest vineyard in the district, that of Mr. Barton, has not been watered for two years, and the enterprising proprietor has actually excavated ditches around his property so as to drain it, to a depth of 6 feet. The Eisen vineyard close by, one of the oldest and best known in the district, is now involved in a suit, which its proprietor is bringing in self-defense against the canal proprietors for flooding his land. It is not only excess in flooding that has to be avoided but excess of seepage, which is just as bad. Not only is the creation of a morass on the surface fatal, but the morass condition below is proportionately injurious. Roots, of course, will not penetrate below the perpetual water line, and thus, if the water rises in the soil the depth from which they draw, their nourishment is liable to be greatly diminished.

It has been suggested that if the pipe method of subirrigation were adopted the same pipes might be made available for drainage. If this could be accomplished without materially increasing the cost it should contain a solution of the difficulty in a few cases, but, as a rule, where drainage is needed subirrigation in any season would be superfluous if not injurious. A remarkable evidence of the rate of seepage in sandy soils is notable in the Fresno district, and that is two little ditches, a foot or so apart, each of them carrying a swift stream of water, which is soaking through the bank of a small canal, and which they divert from the field beyond. A few ditches of this description compose the whole of the drainage work yet done in Western America. Even here the drainage problem does not appear to threaten the requirement of works any more expensive than those already in use, and, except in localities as peculiarly situated, as Fresno, it is improbable that any outlay to provide them will be needed, at all events for many years to come.

CAPILLARY ATTRACTION OF WATER.

For a complete comprehension of these facts, however, it is necessary to read them by the light of a knowledge of a peculiar property possessed by many soils, and which forms a most important factor in all calculations as to the limits of irrigation. It has been found by experiment in California that water rises rapidly in coarse, sandy soils, but only to a moderate height; while in finer soils, whether clayey or of a silty formation, the rise is slower but higher. So that in a few weeks or months, as the case may be, the water attains twice or thrice the height that it climbs to in the former. This has been said to be accomplished by means of a "capillary attraction," in which heat may, perhaps, be an important agent, seeing that the phenomenon is not observed in Colorado to anything like the some extent as in the California slope, and presents the result of experiments made upon different soils to test their capacity in this direction. A consideration of these results points to the superior value in suitable soils of subirrigation, or irrigation by seepage from below, over all methods of surface application, because is is thus possible to avoid caking the soil and loss by evaporation.

EXTENSION OF THE IRRIGATION AREA.

Taking together the facts as to seepage of water from rivers or ditches, and those relating to the rising of water by means of what is called capillary attraction, one is furnished with the key to the gradual diminution of the water necessary for irrigation of the same land, which has been noted in almost every part of the West. In Colorado alone, in situations like that of Greeley, upon a deep, porous soil, with a rapid fall and quick drainage, as much water is said to be used to-day as in the initiation of the practice of artificial watering twelve years ago. Everywhere else the verdict of experience is that the water goes farther every year.

The ranch-owner, who doubted if his spring or brook would suffice for 20 acres, extends the area of his cultivation bit by bit until it reaches 80 or 100 acres, and he still has some to spare.

Bishop Musser, of Salt Lake, who has made an especial study of irrigation in Utah and abroad, states that when the city was first founded there was only water enough from a particular source for 800 or 900 acres, while now the same amount supplies more than 5,000 acres. In another Mormon settlement, named Bountiful, where at first it was supposed that only a few families could be placed on account of the smallness of the stream of water available for irrigation, there are now between 4,000 and 5,000 people, all maintained by means of the same supply. The whole of Utah has been peopled and all its cultivation based upon little driblets of water in this way. Yet the sandy aridity, which is absolutely worthless without water, may be soon over-wet, and it is found that where a piece of ground is fed by good seepage to irrigate it as well kills the crop. Here, as at Fresno, Riverside, Mussel Slough, and in Tulare County, California, may be seen farms and vineyards up to 160 acres in size irrigated solely by seepage from ditches which run along the upper edges of their fields.

The distance that water will penetrate, even without any discoverable dip in the land, has been partially indicated by experiments in subirrigation, when the pipes and orifices, though fifty feet apart, have saturated the whole soil between them. With a fall in the country the seepage extends for far greater distances, and, curiously enough, an instance is reported in the San Joaquin Valley where, upon the construction of a canal, a well a mile or two on the upper side increased several feet in depth after the canal had been some time running.

Another most instructive fact is that as the water supplied diminishes the crops tend to increase. They now raise more grain in Utah with half the water than they did when they concentrated double the supply upon a smaller area. For the first year or so of irrigation the soil becomes soppy, but afterwards, while seeming drier, it is not nearly so thirsty; when it is very shallow flooding ceases and seepage alone is relied upon. Irrigation is said to close the pores of the soil with an infiltration of rich impalpable silt, so that it absorbs more slowly and retains what is absorbed much longer.

Under good cultivation the soil thus enriched becomes far more fruitful than it originally was; but too much water makes the land cold, and eventually turns it into a quagmire. When soakage, as from flooding, is accompanied by soakage upwards by "capillary attraction," the consequence in California is the formation of what is termed "hardpan," an impenetrable layer which resists the entrance of roots and yields them no nourishment. Where this is feared flooding is suspended and the subterranean supply depended upon. Such is the rapidity with which roots push for water, even where moisture can be found, 15 or 20 feet from the surface, no flooding is needed after the first year or two. The roots of vines have been known to penetrate nearly 30 feet in a little over three years, while even lucerne roots travel 15 or 20 feet downwards to moisture. But the catalogue of facts, proving in a variety of ways the injurious effects of over-irrigation, and the marvelous results to be accomplished in time by small streams of water, might be multiplied indefinitely.

THE DUTY OF WATER AND ITS CONDITIONS.

A preliminary doubt as to water measurements has to be taken into account, for until recently different standards have been in use; and still there is, even in flourishing districts, the greatest laxity in applying what standards they have. In Los Angeles, for instance, the zanjero, or water-master, has relied solely upon his eye to judge of the stream a farmer was entitled to receive; and though practice no doubt had enabled him to allot something like an equal share to each person concerned, it is plain that any attempt to define the quantity in recognized measures could only be an uncertain approximation. In every State the use of water for mining purposes has preceded or, in the first instance, overshadowed that for irrigation; and, consequently, what estimates have been made in the past, have been expressed in "miners' inches." This was supposed to define the quantity of water flowing through an aperture an inch square, but, as in some parts the pressure adopted was that of a 4-inch head, while in other places the head was 6 inches, there was evidently abundant room for variation, even in the determination of the capacity of a single inch. When, again, a number of inches came to be measured at once it became possible either to adopt an aperture one inch high and the specified number of inches in length, or to take the square of the whole number of inches as giving the dimensions of the orifice, in which case, again, there was another great cause of variation. The State engineer of Colorado has calculated that the miner's inch in that State has been .026 cubic feet, or, roughly speaking, a fortieth of a cubic foot; and this is now generally adopted as its equivalent, though as a matter of fact, in more southerly States, where water has been scarce, the miner's inch has only meant one-fiftieth of a cubic foot.

Taking into account this initial cause of confusion in the measurement of water, we next find that the quantity of land which any given unit of water will irrigate is governed, first, by the kind of soil, subsoil, the rainfall, temperature, and evaporation of the particular area irrigated, next by the kind of crop grown, and the method of watering it, as well as by the length of time which that land or neighboring land has been irrigated, and lastly by its position with regard to seepage, and its capacity of capillary attraction. It is plainly no easy matter, even when all the terms of the special instance are known, to fix the duty of water under these circumstances. But in almost every instance the records of American experience are wanting in respect to one or more particulars, and hence again there is only room for the vaguest conclusions.

Instances can be quoted in which a flow of one cubic foot per second has supplied 9,000 acres, while in others it only supplies 50 acres. It is vain to attempt to arrive at accuracy in the face of such extremes as these. The manner in which water is sold in the States puts another barrier in the way. A water right there does not mean a right to any given quantity of water, but a right to have a stream of a certain capacity turned into the purchaser's lateral for as often and as long as he pleases. Each farmer accordingly draws upon the supply just according to his fancy in each season. As yet, as there is water in plenty, the Colorado companies do not restrict their customers to the stream they have purchased, but give them whatever flow they happen to have. The farmer, for his part, does not measure the quantity he receives nor yet the quantity which flows away from him, so that on neither side is there any opportunity of obtaining exactitude as to the quantity actually absorbed by the land. Where measurements have taken place, as in Southern California, it has usually been at the farmer's receiving point, from which there is more or less loss, according to the nature of his soil, the make of his ditch, and the distance to be traveled before the field is reached, which renders these almost equally unreliable.

In the face of this array of disturbing causes it is utterly impossible to do more than notice a number of rough generalizations, which have some force in special localities. The more sandy the soil the more readily it receives and parts with water, while, as the soil becomes heavier, it absorbs less, and retains it longer; the deeper the soil the more water is required in the first instance, while with a retentive subsoil succeeding waterings can be greatly diminished. The heavier the rainfall the greater the duty of water in equal temperatures, and when evaporation comes into play the duty has to be correspondingly reduced. Where the land is in a position to receive seepage from higher irrigations, or is so porous as to draw a sufficient supply from its own laterals, or is so saturated as to need for a time no water even in its canals, which are, perhaps, as at Fresno, turned into drainage-ditches, the duty, of course, tends to become nominally enormous. Then, again, small grains as a rule take twice as much water as corn or potatoes, and many times as much per acre as orchards, which are watered on an economcali method. Even the waterings given to one grain, such as wheat, vary according to locality from one to four, oats requiring more and barley a little less. In Riverside the orchards are often only watered once from furrows in winter, and once, twice, or thrice, according to the idea of the owner, in summer. Where flooding takes thousands of gallons the furrow system only requires hundreds, and subirrigation tens of gallons for a similar area, though, of course, under different crops.

COMPARISONS AND CONFLICTS.

Setting aside the question of the actual quantity of water used or needed for navigation, we find that, even comparing the flow of water allotted to farmers for as long as they like, there are the widest differences. Taking the flow of one cubic foot to the second (available during the season for cereals of Colorado, and all the year round for the orchards of California), without making allowance for differing rainfalls, this supplies in Colorado 53 acres; Italy, 70.2 acres (Col. Baird Smith); Utah, San Bernardino, Cal., and France, 80 to 100 acres; San Gabriel, Cal., 120 acres; Fresno, Cal., 160 acres; India, 150 to 200 acres (sira cotton); Los Angeles and Anaheim, Cal, rather over 200 acres; Riverside, Cal., nearly 300 acres; Ontario, Redlands, Cal., Algeria, and parts of India, 400 acres; Sierra Madre, Cal., 580 acres; Spain, as high as 1,000 acres; Pasadena, Cal., 1,665 acres; and by subirrigation, according to one or two experiments, from 1,500 to 9,000 acres.

In Kansas, Arizona, and Mexico the figures given are too conflicting to be quotable. There are the same contrasts as to the depth of water which should be put upon land. In Colorado two or three waterings are given of from 3 to 5 inches in depth; in some parts of southern California waterings of 12 inches in depth have been given, and in other parts a total sufficient in the year to make a depth of several feet. On the other hand, there are farmers in these districts who, according to their own testimony, employ less than half the quantity used by their neighbors, and with equal if not superior results.

If the Colorado farmer were to use all the water at his disposal, he would cover his fields nearly 4 feet deep. The practice appears to be, on the average, to use about one-fourth of this, but there is such a difference in soils that this is but a poor guide. Where a coarse sandy soil, with porous subsoil, can take 10 feet in the season, a fine compact alluvial, with clay subsoil, would be injured with 1 foot; hence, 10 acres of the latter can be irrigated to 1 of the former by the same quantity of water. A natural measure of the duty of water in many places may be supplied by the rainfall of good harvest years, making allowance for the time of fall. In Central California 13 inches during a frostless winter and spring have proved sufficient, and probably if 12 inches could be secured from rainfall and ditch together during the spring it would prove more than ample for flooding cereals.

THE COST OF WATER—THE PRICES PAID.

The prices paid for water are so complicated by the conditions under which it is sold that it is almost impossible to do more than quote the rates in different localities. The water itself costs the appropriators nothing beyond the expense of putting it upon the land, which differs, of course, in every State and every district. This first outlay for works furnishes one clue of an uncertain character to the price of water. Where farmers unite for the purpose of securing a joint supply, they work or pay their share of the construction, and afterwards their proportion of the sum necessary to keep the works in repair, so that it is difficult in many instances to determine exactly what their water costs them. In Colorado it is considered that an irrigable area should be supplied with an outlay upon main-works of £1 or 25*s.* per acre, an estimate which appears to agree, on the whole, with experience elsewhere.

Occasionally, as in Kansas, where very large canals run through very favorably situated country, main-works of a temporary character can be built for as low as 10*s.* per acre, while on the other hand, where special difficulties intervene, as at Salt Lake, in the price to be paid for easements over private lands one finds the canal costing 50*s.* per acre to build. This is by no means the maximum of first expenditure.

With extra works, such as fluming or tunneling, as in Colorado, or wooden channeling, as in the city ditch at Salt Lake, Utah, or expensive piping, as at Pasadena, or the Highlands Canal in Los Angeles County, California, the cost may rise, as in the last two instances, to £8 and £10 12*s.* per acre. Here, of course, the supply is for small areas under intense culture. The greater the scale of the undertaking the less the cost per acre.

The 150,000 acres at Bakersfield, Cal., can be watered by one proprietary for 10*s.* 8*d.* per acre, whereas, if divided into a number of different schemes, adapted here and there to the condition of ownership rather than to the natural surface of the land, it would probably have cost twice as much. Or, take the 76 canal beyond Fresno, Cal., which now supplies only 20,000 acres, at a first cost of about 25*s.* per acre; with an extension of its secondary canals, so as to allow it to supply the 40,000 acres lying under them, the outlay per acre would be reduced to 20*s.*; while if the complete plan, which is for the irrigation of 180,000 acres, were carried out, this would be still further brought down to 15*s.* per acre. Water, therefore, is dearest where the schemes are smallest; that is, where the works are relatively most costly.

The same fact is again illustrated by the price asked for water-rights, which are almost invariably highest in small schemes. Thus, in such "colonies" as Ontario, Etiwanda, or Pomona, Cal., where land is sold in 10-acre blocks, a water-right costs from £15 to £20 per acre, while upon 80-acre blocks it can be purchased in Colorado for £3, in Utah for about 50*s.* and in Kansas for half that sum. Having a water-right, the farmer is then liable only to a yearly assessment for maintenance. This, on the other hand, is highest as a rule where the water-right is cheapest, ranging from 8*s.* per acre in Kansas, and 4*s.* an acre in Utah, to 2*s.* 6*d.* in Fresno, and 2*s.* in several colonies in Los Angeles County.

In Colorado the maximum rate of 6*s.* per acre per annum is rarely charged, the water-right owners only paying the 6*d.* or 9*d.* per acre, which is actually spent on repairs, and the same custom prevails in some parts of Utah; but in both of these instances the schemes are large.

The prices of water rights vary from a variety of causes, such as whether the water owner has land of his own to sell or not, so that particular instances offer but little guide to an exact estimate of their value; nor do they furnish any clew to the quantity of water actually sold.

In Kansas water is paid for according to the acreage of the purchaser, who takes as much as he likes in return for his yearly rental. This most wasteful of practices was tried and abandoned in Southern California, as it will be abandoned in Kansas when water becomes more valuable. Meanwhile its steady increase in price is everywhere noticeable. Thus, at the foundation of Greeley, Colo., 80 acres with water could be purchased for £60; a few years later the water alone became worth £100; to-day the same water right is bringing £200, and with the land is worth £600. In all the "colonies" of California there has been as great a rise in the price of water, though there it is to be found in almost every instance linked to the land. This puts another difficulty in the way of estimating the exact price of water, for though the water is really that for which the money is paid some deduction has to be made for the area upon which it is to be utilized.

Land which in the arid state brings only £1 per acre, is sold at £10 or £15 per acre when under a ditch, and something like this proportion is maintained even for higher priced dry lands, which rise from £5 to £40, and from £15 to £100, when artificially watered.

When the land and the water right are sold apart the canal owner makes two profits, one in the tripling or quadrupling of the price paid for the land, which is his chief profit, and the other upon the water-right, the price of which represents his outlay upon works, with liberal interest added. The first profit, made nominally upon the land, which is often greater than here stated, is, of course, really another profit upon the water, and as the cost per acre of the works is, as a rule, less than the cost per acre of the land, the gain upon the investment in water is much larger than appears. Where there is no sale of land, that is where the water has been brought to land already sold, or for sale by persons other than the canal owners, the price of the water is much higher, reaching sometimes as much as 20*s.* or 25*s.* per acre per annum. At Los Angeles, Cal., water is sold by what is called a "head," which under their loose measurement varies from 2 cubic feet to 4 cubic feet per second, at 8*s.* per day or 6*s.* per night in summer within the city, twice that price outside of its boundaries, and half the price in winter.

At Orange and its neighboring settlements the price for a flow of about 2 cubic feet per second is 10*s.* for twenty-four hours, or 6*s.* per day and 4*s.* per night, and in winter 6*s.* for the twenty-four hours. At Riverside the cost is about 7*s.* 6*d.* per day, or 5*s.* per night, for a cubic foot per second, or 12*s.* for the twenty-four hours. These prices, varying indefinitely as the conditions of sale vary, furnish but an insecure basis for any generalization.

Possibly a better idea of the importance of water than can be derived from any list of purchases and rentals in particular places may be obtained by a glance at its capital value. It has been calculated that the flow of a cubic foot per second for the irrigating season of all future years is worth from £15 to £25 per acre in grain or grazing country to £30 in fruit lands. This is the price paid to apply such a stream to a special piece of land for as long as the farmer may think necessary, the knowledge that an excess of water will ruin his crops being the only limit. But if a flow of a cubic foot per second were brought in perpetuity without any limit as to the acreage to which it might be applied, or the time or circumstances of applying it, the capital value of such a stream in Southern California to-day would be at least £8,000.

PRODUCTS AND THE WATER PRICE.

What price can be paid for water, or land and water together, depends upon the products raised and the price of those products at the homestead, by taking which as a guide consideration of complicated questions as to markets and freights may be avoided. So far as American experience goes, there appears to be no limit to the scope of irrigation, which embraces the fruits and cereals of the temperate zone, as well as the products that are raised only under a tropical sun. Apples, blackberries, and barley are irrigated in Colorado or Northern California, as are rice, cotton, and sugar in the hot lowlands of Mexico. Over a large area of the West it may almost be said that as nothing can be grown without irrigation, anything can be grown by irrigation.

Wherever water has been plentiful and the ground fairly level, it has paid to grow irrigated grain. There are thousands of acres in Colorado and Utah which have never grown any other crop, and are still growing it. The irrigated area under grain in Mexico is very large, and the yield heavy, while it is a moderate estimate that in the States 5,000,000 bushels of wheat are raised by its means.

It is generally calculated that grain can be grown at a profit under irrigation for 2*s.* 6*d.* per bushel, and even where, as in Arizona, the crop has to be teamed 12 or 14 miles across the desert, at a cost of 7*d.* per bushel to railways, upon which the rating is all against the local grower, grain is found to pay. Of course the chief prosperity in the wheat districts was when 4*s.* and 5*s.* a bushel were regularly realized, and a profit of at least 50*s.* per acre was counted upon. All this has changed since the fall in prices, which has brought profits down to 20*s.* per acre, with a yield of 25 bushels. Grain pays still, but very poorly, and, even in better times, it is generally considered the poorest paying crop that can be raised. Still it does pay for irrigation, and this is an important fact to the farmer who cannot afford to wait for the higher returns from intense culture. Nor does grain-growing noticeably impoverish the land where proper precautions are taken against the washing out of the fertilizing matter in the soil, and for the utilization of any sediment there may be in the irrigating water.

In Utah a rotation of crops is adopted; but in Colorado are to be found instances where grain has been grown every season for ten or fifteen years without perceptibly injuring the land. In Arizona and Mexico the native population have raised their wheat and Indian corn from the same plots for scores, if not hundreds, of years; and to them the idea of manuring is quite unknown. Here and there a farmer may be found who takes the pains to use the droppings of his stock upon his fields, but this is the exception. As a practice, systematic fertilization is unthought of; and so far no serious injury appears to have resulted from its neglect where any falling off in yield has been followed by change of crop. This is of interest as showing at all events that the need of expensive restoration of the soil is not likely to assert itself in our richer lands until after some or perhaps many years of irrigation. Neither does the grain itself suffer if the seed be carefully selected. In Southern California irrigated wheat has a slightly thicker skin, makes more bran, and to the practiced eye is slightly darker in hue than that from the wet northern region, but it is said even there to be fully equal in quality to unirrigated wheat, a testimony which was repeated by millers in Mexico, Arizona, and Colorado. It is not from any such fallacious anticipations that grain-growing by irrigation is condemned in the States. Though all kinds of grain can be grown well and at a profit, the growing is considered a mistake, because the profit is too small. Land and water that will grow grain will yield crops which are much more remunerative. Grain may be taken in rotation with potatoes, which flourish under irrigation in a sandy loam, or with peas or lucern, which act as restoratives to the soil. All kinds of root crops and all kinds of vegetables can be grown, and are grown, usually at a somewhat higher profit than grain. These again have as a rule a smaller profit than can be obtained from stock, which, in its turn, yields to the profits derivable from grapes and fruit.

STOCK-RAISING ON IRRIGATED LAND.

It is a more remunerative occupation to grow beef and mutton or bacon, for which there is just as steady a demand. Two-thirds of the 50,000 acres irrigated at Phœnix is under grain, but this little valley also raises its 100,000 hogs. Dairy produce is successfully raised in Northern California by means of irrigation, where, indeed, it is applied to little else on account of the regular and sufficient rainfall which can there be counted upon. Even in Australia many towns owe a considerable proportion of their vegetable supply to the Chinese irrigator. It would be a mistake to ignore these minor ways in which irrigation can be very profitably employed, especially in the neighborhood of centers of population, but it would be an equally great mistake to suppose that irrigation is only practiced on this scale. A prevailing misconception as to irrigation is that it is employed only for small areas under high culture. The fact that great stock-growers in California, such as Messrs. Haggin & Carr, or Messrs. Miller & Lux, irrigate thousands of acres for stock purposes appears to be lost sight of. Much Mexican irrigation is carried on upon the same plan. Where the great land-owners have their immense estates, one can see not hundreds but thousands of acres artificially watered; and where smaller proprietors enjoy a share of the coveted irrigable area they cultivate so closely to each other's borders that the fenceless area as far as the eye can reach appears one gigantic irrigated field. The great valleys of the Ortiz, the Concho, the Florido, and the Nazas, the wide sloping plains of the Laguna country in the neighborhood of Lerdo, and in the province of Leon exhibit the patient industry of the peasants and a marvelous fertility secured by means of an artificial water supply of the rudest character. On the great cattle and sheep ranches of New Mexico the proprietors, some of them Australians, are enlisting the same invaluable ally in order to protect themselves against the occasional ravages made in their flocks and herds by bad seasons. It pays as a rule to irrigate natural grasses, for by this means the carrying capacity of land is increased 33 per cent. The Chowchilla Canal, in Fresno County, California, 30 miles long, 30 feet wide at its mouth, and 2½ feet deep, is used almost solely for this purpose, and there are 20,000 acres of natural-grass land irrigated in one property in Kern County.

THE VALUE OF ALFALFA.

But the mainstay of the American stock farmer, large and small, is lucern, there styled alfalfa, which, though unsuccessful in England, is highly prized in France. In every Western State this is grown to profusion. There are 35,000 acres of it grown by irrigation at Bakersfield. In Yolo County, California, almost the whole of the 13,000 acres watered from the Woodland Canal is under lucern; it is to be found upon almost every colony plot in Southern California, and is the surest source of revenue in Utah and New Mexico. The area planted with this crop is increasing with marvelous rapidity. It is said to carry 10 sheep or even 20 sheep to the acre if it be cut for them. It is not a new growth in Victoria, but without irrigation its marvelous qualities have only partially developed themselves. At Dookie, with only the natural rainfall, it can be cut but once a year, yielding about three-quarters of a ton to the acre; while at Bacchus Marsh, with irrigation or water within reach of its roots, it can be cut five or six times, yielding 7 or 8 tons, and lasts fifteen to twenty years.

There are some 300 acres of it in this locality, thriving upon a natural seepage, and though rather delicate in its earlier stages, owing to the lack of irrigation, when once firmly rooted it raises the value of the land to from £50 to £75 per acre. It is sown broadcast and freely, with a little wheat, oats, or barley mixed in it; is rarely manured, though better for an occasional scarifying and top-dressing; is never fed down, but cut early and often, and found to possess splendid fattening qualities. Under irrigation lucern seems to flourish everywhere, particularly in sandy loam, and in a warm climate free from frost, and though the yields given vary, they are all great. Three cuttings are sometimes obtained in the first year, making a total crop of 4 tons to the acre, but the general thing is, as in Utah, to obtain only one crop in this period. After this 6 tons are expected in the second year and 8 to 12 tons in the third year. There are poor soils where it is cut only twice or three times, and other soils on which its quality does not keep pace with the quantity, but on those that most resemble our own plains the cutting is rarely less than four times and the yield generally over 10 tons per acre in the course of the year.

FRUIT-RAISING BY IRRIGATION.

But the products for which irrigation is most necessary, and in which it yields the largest, are grapes and fruit. The great land-owner in America not only plants his thousands of acres of lucern and perhaps his ten thousand acres of grain, but, with incessant enterprise, plants his hundreds of acres of vines and fruit-trees. When irrigation is employed, however, the production is almost wholly in the hands of small proprietors, men often of some education and some capital, who have found an attractive field for the exercise of their intelligence in bringing small allotments into a condition of the highest productiveness. Judging by the results obtained in Southern California, to which this class of cultivation is as yet chiefly confined, it has not proved an unprofitable speculation. It is safe to predict that in a short time grain-growing will be given up on all smaller areas of irrigation and that a commencement will have been made upon the larger tracts to follow the same example. It pays better to grow fresh vegetables for towns or can them for export, or to establish chicken farms or bee ranches than to raise grain for export. Already in Northern California the great farms, so famous a few years ago for their yields and extent, are being cut up into vineyards and orchards, and where along the old mining ditches any vintage ground can be secured it is being put to the same uses.

Twenty acres under vines or fruit-trees are preferred to 160 acres under grain. There is more regular employment and more regular leisure, with less stress at a particular season for adult male labor. An acre in raisins was reckoned as valuable as 5 acres of wheat, when the price of wheat was nearly twice what it is now.

The fruits grown are oranges, lemons, limes, apricots, pears, figs, peaches, pomegranates, nectarines, apples, plums, quinces, cherries, olives, almonds, walnuts, and chestnuts. From some of these two crops a year are obtained, but of course none of them bear for some time after planting. This is not all lost time to the American farmer, who grows great crops of vegetables between his fruit trees until they are ready for bearing. The period during which no return is expected, even under irrigation, is considerable; as, for instance, it is for peaches, apricots, almonds, and vines, four years; for oranges, ten years from the seed, five years from the bud; olives, from seven to ten years, unless the Spanish practice of planting branches is followed, in which case it takes only two years; and walnuts seven years. When the profits do come, however, they are proportionately large.

Nearly 50 per cent. of the fruit grown in California is canned, but only 5 per cent. is dried. The production is increasing enormously every year. Vineyards are utilized not only for the supply of grapes but of raisins and wine; and there is no branch of production into which capitalists and small farmers are now entering upon a greater scale or with more confidence than wine-growing. The clearest heads in California consider the overproduction of wines or raisins an impossibility, and experience is teaching them that at existing prices the investment is remunerative, although wine-making is developed in the face of a prejudice quite as unreasoning as that which has till lately faced colonial vintages. For other fruits, though drying is occasionally adopted, the chief reliance is upon the canning process practiced in every fruit-growing center. The taste for fruit, whether fresh, dried, or canned, is one that appears to grow by what it feeds on, for the demand in America seems to increase almost as fast as production. The markets of the East are, of course, open to the irrigating West, but rates of transports are relatively high, and competition from the West Indies and the Mediterranean is keen, so that it can scarcely be said to be a home market in the ordinary sense of the term.

The injurious effects of overirrigation are just as potent in fruit-growing as in every other crop. It is claimed on the authority of a commission of experts, appointed by the French Government to inquire into the remedies for phylloxera, that regular furrow irrigation in summer keeps the disease in check, but it has been proven in Fresno that an excess of water injures both the wine and raisin qualities of the grape. There is a special disease to which orange trees are subject which strips the tree of its leaves, prevents the fruit from coming to maturity, and finally kills the tree, which a special committee of the Southern Californian Horticultural Society, after an exhaustive inquiry, has declared to be wholly due to overirrigation and deficient cultivation. The citrus family can endure more water than any other class of fruit-tree, but it is clear that the limit of the water consumption of any of them is soon reached, and that to go beyond it is injurious if not fatal.

PROSPECTS OF IRRIGATION IN AMERICA.

We have now taken a rapid glance at the products of 2,500,000 acres of Western America, watered by 12,000 miles of main canals and 120,000 miles of subsidiary ditches, at an expense of many hundreds of millions of dollars. The estimates of the value of the yield from irrigated vineyards and orchards are not official, but those engaged in supplying the markets put the production of Californian vineyards this year at £1,000,000 and of the orangeries and orchards of the same State at half as much again.

A good deal of fruit is grown for home consumption in neighboring irrigating States, but prohibitive railway rates have prevented the full expansion of this and other classes of production. Utah and Colorado, entirely dependent upon irrigation, draw their revenue from other classes of products—the latter in 1883 raising in value £1,100,000 of grain and root crops, the former £700,000. To assess the total value of the products raised by means of irrigation, many of which could not be raised without it, would be no easy undertaking; but it is quite clear from the statistics that it must be expressed in millions sterling. Adding the enhanced stock-bearing capacity of the country, and the value of industries not directly productive which are dependent upon the irrigating settlements, would make up a grand total that would probably surprise the Americans themselves. There is no reason to suppose that the list of products capable of being profitably grown under irrigation is yet exhausted. Experiments are continually being made with fresh crops, and the result is generally favorable where climate and soil conditions are studied. Great as the produce of the artificially-watered West now is, the prospects are that it will become very much greater; and the opinion of those qualified to form a judgment is that irrigation, marked as have been its successes, is yet in its infancy, and has given no more than a promise of what it is destined to achieve.

HEALTHFULNESS OF IRRIGATED LANDS.

There are irrigated lands in which health seems entirely unaffected; there are others where the influence of malaria is but too patent, and the task is to discriminate between them. The river bottoms, as they are termed, flats, but little raised above the level of streams, are, throughout the southern parts of the United States, recognized as malarious whether irrigation is practiced or not. Fever, ague, and chills are prevalent in such localities in Missouri, in Louisiana, as in the southwestern area. From their position these lands are easily irrigable, and hence settlers are tempted upon them and become subject to the same complaints. Whether irrigation, as is probable, increases the danger in such spots is not known, but in places similarly situated, though not malarious previous to irrigation, it seems that the practice has acted injuriously. Where the soil is saturated and artificial morasses are formed, as at Fresno, fever is naturally found in the immediate neighborhood. Along the lower lines of this district the miasma rises to a height of 10 feet, and here, as in the counties further south, the sleeping-rooms are always placed in a second story in consequence. Much of this region was malarious before irrigation was practiced, and in parts the formation of channels is said to have actually reduced the danger. This, however, in such circumstances, can only be entirely removed by complete drainage. Much importance is attached to the source of the water drank, and wells are sunk to great depths so as to avoid all seepage, and secure a pure supply.

On the bench, or mesa lands, of California or Kansas, in those of Colorado, with their rapid natural drainage, or in the porous lands of Arizona and New Mexico, malaria is as yet unknown; nor does there seem much prospect of its appearing. It is feared only in lands naturally swampy, or readily made so. It is not regarded as a fatal complaint, though the repeated attacks to which its victims are subject necessarily have a permanently weakening and depressing effect. There are many who seem to escape even in these localities, but there are others whose sallow and sickly looks only too plainly indicate the presence of malaria.

UNITY OF LAND AND WATER.

Another matter arising out of American experiences which it is desirable to notice is the relation between the ownership of land and that of water. Where a farmer has his own canal to his own land no question arises. Where a number of farmers excavate a ditch and parcel the water out between them, the only question is as to whether the water used by each can be applied where he pleases, or whether it must be applied to particular acres specified in the contract. If he can sell his water to another or turn it upon new land, the business of the company becomes more complicated and the value of the lands first irrigated is not so well maintained. If, however, as is often the case, the farmers have been unable to make the ditch without assistance and have called in a capitalist to join them, he frequently arranges to take up a certain amount of unoccupied land which can be served by the canal and from the sale of which he looks to derive a considerable share of his profit. To prevent competition, therefore, he generally stipulates that the water-rights which the farmers receive in return for their investment of labor or capital shall attach to their particular acreage and can not be transferred to any other land. By this means he secures for himself the market for all irrigated land outside of these acreages. When he sells what land can be irrigated by his share of the water his interest in the canal determines, and the works become the property of those who own the various ear-marked acreages which it is confined to supplying, unless by common consent the proprietors then decree otherwise.

Capitalists often construct canals into unoccupied country as a speculation, and sell so much land with a right to so much water attached until rights covering the whole flow of the canal are parted with, and the new owners of the land become joint proprietors of the work which feeds it. In this way land and water are bought and sold together, the area of the land being measured by the quantity of water; for, in the West all value may be said to inhere in the water. Land is plentiful and almost worthless. The owner of the water really owns the land, for it is useless without his supply. The quantity of available water, and not the area of a territory, defines its agricultural extent; consequently, where capitalists have built canals to lands which they do not own and have secured the water, they have really acquired the land too. They have the farmers absolutely at their mercy, and enjoy a monopoly of a most arbitrary kind. A land-owner who obtains a water-right can carry a stream to his own property at a distance through land as good as his, which never can be cultivated except with his consent, and which will fetch only one-tenth of what his irrigated land will fetch, though the two are only divided by a fence.

A recognition of the danger of allowing water to be monopolized without regard to the land has led a commission appointed to inquire into Californian irrigation to declare that, "as a matter of public policy, it is desirable that the land and water be joined never to be cut asunder; that the farmers would enjoy in perpetuity the use of the water necessary for the irrigation of their respective lands; that when the land is sold, the right to water shall also be sold with it, and that neither shall be sold separately." Major Powell, in his careful draft of a land system adapted to the arid region, most emphatically recommends that "The right to use water should inhere in the land to be irrigated, and water-rights should go with land titles." In Colorado, the feeling has gone so far that a proposal has been made in the legislature to compel all canal owners to supply any persons with water, which they are not themselves using, at fixed rates; but as this would simply mean transferring to land owners who had invested nothing in canals part of the profit to be made by those who had so invested, the proposal was not entertained. Indeed, where the companies, as at Denver, sell the water-right with the land, and then contract to maintain a water supply in perpetuity for a fixed sum per annum, the system is unobjectionable, providing that, as in these cases, the water-right has been properly obtained.

In Colorado and Utah, notwithstanding their peculiar situation, the water is given to the first applicant, though he has to purchase the land to use it upon, which without the water would be worthless. It would have been more economical and more simple to have sold the water and given the land. Be this as it may it is essential that they should always go together. The practice of tying water-rights to the land has another argument beside that of avoiding monopoly, and this is that it tends to a more careful use of the water by its concentration upon a smaller area.

THE COLONY SYSTEM.

At first, as at Greeley, colonies were established upon something of a communal basis beyond the joint ownership of water-works, but this is now very rare. It is still frequently the case to find them organized upon a temperance basis, or by the union of those of the same nationality, as in the Scandinavian and German colonies. The joint interest in the sources of their irrigation supply remain, but all other kind of community has disappeared. Under the most favored plan, a piece of irrigable land is marked out into small holdings; either the land owner or a company construct works to supply these with water, and the lots are then sold to any purchaser with water-rights attached. By liberal advertising, and easy terms of sale, new centers of population and production are created in this way in a very short time, so that the barren plain, in the course of a few years, becomes dotted over with these oases until one joins another, and at last they inclose and support a thriving and well-built city, such as Fresno is to-day. Altogether there are some fifty of these colonies in California, some of them planned upon a large scale, such as Riverside, and containing their township within themselves. It becomes the interest of the original owners to make the advantages which their lands offer widely known, and, consequently, they turn themselves into emigration agents of the most energetic kind. The Eastern States are deluged with pamphlets, even the Old World is reached by means of the printing office and by correspondence through the relations of those already settled. The aim is to make the place attractive, and no expense is spared to insure success. In one such enterprise at Ontario, the proprietors have laid out nearly £100,000 upon 8,000 acres of land, bought at 28s. per acre; of this sum about £10,000 was spent upon head-works for the water supply, which is conducted in 26½ miles of cement pipes to the corner of each ten-acre allotment, and in 3½ miles of iron pipes to the township for domestic purposes, at a cost of over £10,000. More than £20,000 in land was given to establish an agricultural college now built in the center of the settlement, nearly £4,000 spent in planting trees and making streets, and £700 in securing a railway station. There is a double avenue running through the colony 7 miles long in a straight line, and 200 feet wide, planted with eucalyptus trees, and intended to contain a cable tramway, and from the masts of which will be suspended electric lights, run by hydraulic power. Over £7,000 was spent in advertising this colony, and the result is confidently awaited. Many persons, weary of city life, are drawn from the New England States, while numbers are attracted from the Old World by the inducements held out to them.

The colony enterprise has many advantages for those who engage in it. To join in it does not imply so great a trial as that of facing the wilderness with no neighbor less than miles away. It permits of society, of the establishment of schools, churches, and libraries, and the enjoyment of comforts which cannot be secured in isolation. It furnishes, in fine, a framework for commercial organization and the beginning of local government. It appeals, too, to a larger class than that usually drawn to agriculture. The physical labor required is not so severe; there is more scope for intelligence, and it offers remunerative employment for a small capital.

SMALL HOLDINGS UNDER INTENSE CULTURE.

This is due not to the colony organization, but to the fact that by means of irrigation small holdings under intense culture are proved to be profitable. The land and water which will produce 25 to 35 bushels of wheat at 2*s*. 6*d*. per bushel will produce, under fruit trees, a crop worth twenty or thirty times as much. One-twentieth or one-thirtieth of the area under fruit instead of grain will yield as great a return and a larger percentage of profit. It has been found in parts of Europe where the water is the property of one owner and the land of many others that the tendency of irrigation is to establish a monopoly in land. This is the case whenever the water is not attached to the land, and owing to a defective code lawsuits are frequent. But where water is attached to land, and rights are indisputable, there is exactly the opposite tendency—to cut up the land into small farms. It needs both men and money to prepare and plant 20 acres of fruit trees at once. It is as much as a hardworking man can do to attend to 20 acres of oranges or 25 acres of vines himself, and then he needs light assistance in the picking season. It is calculated that he can by frugality maintain himself and family upon half as much. Hence in the colonies 40 acres is a large estate; it requires hired labor and yields a considerable revenue.

Whether colony life yields large profits or not, the visible evidences are all of prosperity. The little holdings are neatly tilled, with an air of perfect security, owing to their being often unfenced or fenced only by a row of trees; the houses are neat, well finished, well furnished, and of some architectural pretensions; the people are comfortably dressed and well nourished, and their cattle in capital condition. Many of them brought their savings with them, and they are apparently content with their investment. The poorest places in these colonies have a far greater air of comfort than grain farms of two or three hundred acres in extent. Whole colonies have been settled direct from Europe by a peasantry trained to the most frugal and industrious habits, and with these success is immediate. The much more extravagant American has a harder time of it, if he starts upon his 10 acres with less than £500, as he must maintain himself by laboring for others the greater part of his first three or four years. Still there are numbers who enter upon their little plots without even the money to pay for them or build a house, or buy their tools. Many of these are dependent upon advances from the land companies, and, though interest is charged, the general result is that in a few years the hardy colonist has his homestead clear, and a profit from it which, in a few years more, suffices to maintain him, and employ him always upon his own land. Ten-acre blocks are gaining in favor in some districts, and nowhere can one observe deserted colonies, or parts of a colony, which show signs of the total failure of effort.

WHAT HAS BEEN ACCOMPLISHED UPON SMALL HOLDINGS.

The success of small settlements in Utah is evidence of what can be accomplished in the face of the greatest difficulties. The tide of immigration constantly pouring into Salt Lake City consists of families often entirely destitute, and who have, as a rule, to become indebted to the church for their start. They have nothing but small plots of bare land, barren by nature, and are obliged from the very start to yield tithes yearly of all they produce; to give their labor to make the ditch which brings them water, and buy back their debts to the church with interest. Yet these peasants are enabled to make homes for themselves, which, though plain, are not uncomfortable, and to steadily improve their credit, though trading at the store established in the church interest, which is not obliged to offer the lowest prices.

With these lessons in the value of intense culture, it is not surprising that the most intelligent and most enterprising irrigators desert grain-growing for either stock-raising or fruit-growing as quickly as possible, nor that the newspapers and authorities of weight are persistently bringing before the eyes of others the relatively unprofitable character of wheat-growing, and urging them to attempt higher culture, for its increase means the increase of population and of natural wealth Railway accountants in California calculate that an acre in vines gives as much freight as 9 acres of grain. A 640-acre grain farm can be managed by a farmer with two grown-up sons, except in harvest time, and at all other seasons the broad, bare fields and rude homestead are not indicative of permanent improvements.

On the Barton vineyard at Fresno, which has 540 acres under vines, thirty men are employed all the year round, without pickers. The winery, which is to receive the 600,000 gallons upon which the proprietor calculates, is a great building, 330 feet long by 96 feet wide, besides which there is a distillery and office in addition to the usual farm buildings surrounding a handsome residence and garden. The capital invested is £60,000 and the amount spent annually upon the 330,000 vines nearly £5,000. Thus under intense culture the same area as the grain farm is made to produce a hundred-fold. With 640 acres under grain a farmer's position is precarious without irrigation, and but poorly profitable with it. Under fruit or vines it is a great estate and its owner a wealthy man. The Barton vines are used to produce wine, while on small holdings they are usually employed to make raisins. It is calculated that the value of the products of Riverside will in the course of a few years be £200,000 per annum, and, though the oldest, it is not the best managed colony in California.

THE POLICY OF THE STATE TOWARDS IRRIGATION.

Though there are lessons in American experience, already referred to, which have convinced the leading politicians of the States interested that certain legislative and administrative duties should be undertaken by the Government, there is nothing either in their policy nor in their experience which casts any direct light upon the problem whether the State should assume any other attitude towards the man who increases the natural production and his own wealth by irrigating than it assumes towards the man who accomplishes the same results by reclaiming or clearing his land. The conclusions as to State action which have been accepted among so self-reliant a people would be worthy of attention, if it were only because of the national tendency to which, in a measure, they run counter.

Though they have been alluded to before they are of so much moment that they will bear repetition, more especially as, if now called upon to offer suggestions as to the duty of the State towards irrigation, I could find firm foothold in American precedent for just the recommendations which would be made by the irrigators of Colorado or California.

WHAT THE STATE SHOULD DO.

Their verdict, based in the first five instances upon a practical trial in one or other of the irrigating States of the course advised is, that—

(1) It is essential that the State should exercise the supreme control of ownership over all rivers, lakes, streams, and sources of water supply, except springs rising upon private lands.

(2) That it should dispose of the water to those desiring to irrigate on such terms and conditions and to such an extent as may be determined by professional or qualified officers of its own, its object being to encourage the greatest possible utilization of the water on the largest possible area.

(3) To insure this it should establish a scale of water measurement and insist upon its employment in all transactions relating to water.

(4) The State should appoint local water-masters to supervise the distribution of water, settle disputes, and exercise such a jurisdiction under a central office as shall guarantee the preservation of water courses and other sources of supply.

(5) Power should be given to holders of water-rights to obtain easements over private lands on payment of compensation and proof that the route asked for by them has been selected for sufficient reasons.

(6) The State should furnish the fullest information as to the natural capacities of its territory for irrigation. The United States has already recognized its obligation in this direction.

(7) In California it is also held that to prevent all irrigation from necessarily falling into the hands of capitalists, or any scheme for the general benefit from being negatived by one or two refractory land-owners, there should be a means of organizing irrigation areas and creating corporations for them, who should be capable, at the bidding of a majority of those interested, of doing all things necessary to the construction of works and distribution of water by means of funds borrowed upon the common security. Here, again, the State officers would be employed in protecting the public interest and testing the plans of projectors.

It seems to me, however, that without departing from methods approved elsewhere, we might go farther and adopt some of the minor forms of State encouragement already in operation in Europe. Even in America, judging from what is sometimes done in other ways, there would be little opposition to proposals for holding out inducements to the study of irrigation, theoretically and practically, as best adapted to local conditions. Such means of encouragement are used in France, in which country may be found a precedent for the dispatch of the writer to Western America, where, some two years ago, a similar visit, with exactly the same objects, was paid by an official representative of the French Government.

APPENDIX NO. 2.

WATER SUPPLY AND IRRIGATION IN MEXICO.

Through the courtesy of the Mexican minister in this city, Señor Don Matias Romero, and of the Government of the Mexican Republic, the information given below in regard to water supplies and irrigation in Mexico has been collected through the state and local authorities of that country and made available for the use of the Department in this report.

On the 24th of December, 1885, a letter was addressed to Mr. Romero requesting him to furnish the Department with such information regarding the water courses and springs of Mexico, the system of irrigation there in operation, and the laws bearing upon that subject as he might have at hand.

The following reply was promptly received from Mr. Romero:

MEXICAN LEGATION, WASHINGTON, D. C., *December* 25, 1885.

RESPECTED SIR: Permit me to acknowledge the receipt of your communication of yesterday, in which you ask me for information regarding the water courses and the supply and irrigation in Mexico or the laws relative to the subject which I may have at hand, and requesting that the same be sent to Hon. J. R. Dodge, Statistician of your Department.

I have written to my government requesting that these documents be forwarded to Mr. Dodge, according to your orders, as soon as possible.

Meanwhile, I remain, very respectfully,

M. ROMERO.

To Hon. NORMAN J. COLMAN.
Commissioner of Agriculture, Washington, D. C.

On the 5th of January, 1886, a letter was addressed by Señor Eduardo Garay, of the Mexican department of state and foreign relations, to the minister of public works, requesting the latter to furnish the information indicated in the letter of Mr. Romero. On behalf of the ministry of public works Señor M. Fernandez replied that no official data on the subject of water supplies and irrigation in Mexico were in possession of that department, but as regards legislation on the subject the ancient Spanish laws had been adopted in federal affairs, while in local concerns the civil codes of the respective states or districts were observed in the measurement of water, in accordance with the statute of August 2, 1863. He added, however, that in a circular addressed to the governors of the states, the federal, district, and the territories, he had requested information on the subject, which would be communicated as soon as practicable. The circular referred to bears date February 22, 1886, and the following is a translation of that portion of it which related to the subject under consideration:

"SEC. 4. Being frequently called upon by foreigners for reports upon the water supplies for agricultural and other industries, as well as for information regarding legislation upon this subject, and believing it to be of great importance to be able to give exact data upon these points, I beg you to furnish to this department accurate reports relative to the currents and courses of water in your state, explaining, if possible, at what point each river has its source, and into what water it empties, the localities through which it flows, and the uses which are made of its waters—giving an idea (even approximate) of the volume of water in cubic meters, stating, besides, whether the waters are permanent; *i. e.*, whether the flow is continuous or whether they flow only a part of the year.

"In the latter case state the months in which they flow. Of equal importance is other information relative to natural deposits of water, such as lakes or lagoons, and ponds, also artificial deposits, such as cisterns and reservoirs, giving their length, width, and depth.

"Give also complete information respecting the laws of your state which govern the uses of water for irrigation and as water-power. I also recommend to you that in accepting this mission for the government you should use the utmost care that the data be exact, and that the information be given in a clear and concise manner, to the end that in giving publicity to the same the greatest amount of usefulness may be obtained for the benefit of our republic and of foreign countries."

In reply to this circular a large amount of information was soon forwarded from local authorities to the central Government of Mexico, showing in much detail the sources and courses of streams, with estimates of their volume and other particulars, as well as many facts in relation to other water supplies mentioned in the circular. So far as it relates directly to irrigation, the information for different States and Territories thus far published in documents received from the Mexican Government is summarized below.

LOWER CALIFORNIA.

The sub-prefect of the northern part of Lower California, reporting on the water supplies of that district, mentions the Colorado as the only important river in the district, and refers to information in regard to that stream already in possession of the Mexican Government. After enumerating various smaller streams and a few ponds and lagoons, which furnish drinking places for cattle, he says:

"None of the waters to which I have referred are used for agricultural purposes, because the small grains—oats, wheat, and barley—which are cultivated in this district belong to the temperate zone and are grown in winter. Corn, beans, and other products of this nature are planted only in damp soil, which does not need irrigation."

DURANGO.

The political chief of Oro, in the State of Durango, writes to the secretary of state of that commonwealth that in the district under his authority there are thirteen hot springs, some of which are used to good advantage in the irrigation of gardens. The rivers which fertilize a large part of the district are the Ramos and the Sestin, which unite to form the Nazas. The Sestin, from the neighborhood of Cerro Prieta to its confluence with the Ramos, has a length of about 60 leagues (156 miles), its greatest breadth being about 328 feet, and its general depth about 5 feet. The Ramos has a length of about 31 miles, with an extreme breadth of about 260 feet and an average depth of somewhat over 3 feet. The waters of these streams, whose volume may be estimated at about 25 cubic meters (882 cubic feet), are utilized in agriculture with very good results, wheat and maize being the favorite crops, and yielding the best returns when the precipitation of the rainy season is largest. Besides these rivers there are many small streams which, without being permanent throughout the year, afford sufficient water to make them useful in the irrigation of gardens. There are some unimportant ponds in the district, but no lakes or lagoons.

A law passed by the legislature of Durango, and dated November 11, 1881, contains substantially the following provisions:

No one is allowed to construct on the rivers or other waters belonging to the public, or along their banks, any new works, or to alter existing ones in such a manner as to change the direction, height, breadth, or depth of the dams, dikes, or aqueducts, without previous license from the public authorities.

Any person desiring such a license is required to state in writing to the proper local authority the kind of work which he proposes to execute, the materials of which it is to be constructed, its dimensions, and other necessary particulars, and the place where it is to be made.

The authority receiving application for license to construct works on the public waters or their aqueducts will note in writing the day and the hour in which it was presented, and will give the desired record of it. The same authority will publish the petition by posters in the locality in which the petitioner resides or by newspaper if there is one. A copy thereof will be furnished to the corporation attorney, so that within eight days the latter may give his opinion whether the proposed work will or will not be prejudicial to the public interests. This opinion will then be sent with the petition itself to the state government. The opinion of the attorney will be accompanied by that of an expert consulted by him, whose fees will be paid by the petitioner.

The petition, having been received by the state government, will be published in the next three issues of the official journal. If during its publication, or within eight days thereafter, no opposition is made to the proposed work, and if no objection shall have been set forth in the opinion of the corporation attorney, the state government will authorize the execution of the work, and will cause copies of all records in the case to be sent to the party interested, for whom they shall serve as evidence of title. The same should also be inscribed in the public register of property.

Any one desiring to oppose the execution of a work must present himself in writing to the state government within the period indicated in the last paragraph. On receiving such notice of opposition the government shall immediately have it sent, with a record of all its antecedents, to the judge having primary jurisdiction in the locality to which the proposed work appertains, in order that he may decide whether or not he ought to prevent its execution on account of its being in conflict with some acquired right, or causing, either to the public or to the individual opposing it, detriment for which indemnity cannot be obtained.

If the damage which the work would cause is such as can be indemnified, the judge shall cite the person proposing to construct the work and the person opposing it to a verbal conference, to the end that they may mutually agree on the indemnity to be paid.

Whenever it shall appear that the opposition to a work is unfounded, the person making the opposition shall pay the costs of the proceedings thereby necessitated; and if there shall also appear to be rashness or malice in the opposition its author shall indemnify the party opposed for all the damages suffered through the delay in carrying out the work.

The amount of indemnity having been fixed, the work shall not commence until it is paid.

Judicial proceedings arising under this act will be in summary form, as provided by the code of civil procedure.

A decree having been pronounced, the records received from the State government must be returned, and with them must be sent an attested statement of the action of the local tribunal.

Changing the course of a river or other stream of public use, or draining off its waters by means of works constructed in it or on its banks, is absolutely forbidden.

In cases of urgent necessity, to prevent inundation, the destruction of embankments, reservoirs, or aqueducts, or other damages equally serious, permission may be granted for the construction of such works as the authorities may deem necessary. But if any work constructed under such circumstances would interfere with other works previously existing, it cannot remain longer than the circumstances continue which render it necessary, unless permission be obtained under the provisions of this act, and such permission shall be applied for within three days after that of the local authorities is solicited. The latter authorities are required to apprise the State government of their action in cases of the class to which this paragraph refers.

The preceding provisions do not apply to the partial or total reconstruction of works already existing, or which have been executed according to this law, and which are not to be changed in their direction, height, breadth, and depth. A person having occasion to make partial or total reconstruction of any work conformably to this paragraph must notify the local authorities, so that they may assure themselves that the work proposed is really one of repair or reconstruction.

So far as they are not in conflict with the present law, the provisions of the civil code and code of procedure relative to the use of public waters, or to servitudes or works connected therewith, are left in force.

This law was promulgated on the 10th of November, 1881.

JALISCO.

Under date of Guadalajara, May 1, 1886, a report on the streams and other water supplies of this state was addressed to the minister of public works. The following particulars bearing on irrigation are obtained from this communication:

The principal rivers which traverse this State are the Cuitzeo (sometimes called the Tololotlan) of Santiago, or Grande, the Verde, the Juchipila, the Lerma, the Zula, or Atotonilco, the Ayuquila, the Tuxpan, the Chacala, the Ameca, the Bolaños, the Apazalco, the San Pedro, the Acaponeta, the Cañas, and the Camotlan, most of which are also known under other names. The largest of these streams is the Cuitzeo, which rises in the town of that name, and after a course of 98 leagues (255 miles) enters the ocean to the northwest of San Blas. Its average flow is about 111 cubic meters (3,920 cubic feet) of water per second, and its use in irrigation, which is now small, might be largely increased. Opposite the town of Juanacatlan there is a cataract about 65½ feet in height, which would furnish power to the amount of about 30,000 horse-power, of which only the amount required for one flour-mill is now utilized. There are many points along this river, or near it, where hydraulic wheels after Poncelet's system could be advantageously used.

The Verde, which rises in the State of Zacatecas, is a tributary of the Cuitzeo, and for a distance of 47 leagues (122 miles) its course lies within the State of Jalisco. Its waters, which have a flow of 50 cubic meters (1,766 cubic feet) per second, are utilized in irrigation to some extent, and by means of lateral canals they might be largely employed in working hydraulic motors.

The Juchipila, another tributary of the Cuitzeo, rises in Zacatecas, and its course lies within the State of Jalisco for only 17 leagues (about 44 miles). It has an average flow of 16 cubic meters (565 cubic feet) per second, and is utilized in irrigation.

The Lerma, which rises in the Almoloya region of the State of Mexico and empties into Lake Chapala al Oriente, flows through Jalisco only 12 leagues (about 29 miles). It has an average flow of 80 cubic meters (2,825 cubic feet) per second, but is available for irrigation only when its waters are high. This stream presents more advantages in the States of Michoacan and Guanajuato than in Jalisco.

The Zula rises within the State, and has a course of 30 leagues (78 miles) before emptying into the Cuitzeo. It has a flow of 8 cubic meters (282 cubic feet) per second, and its waters are employed on a small scale in irrigation.

The Ayuquila rises within the State, and after a course of 70 leagues (182 miles) empties directly into the Pacific. It has a rapid current throughout almost its whole length, and although it has an average flow of 30 cubic meters (1,059 cubic feet) per second, it serves to irrigate only small areas.

The Tuxpan rises within the State and empties into the Pacific, receiving in its course of 60 leagues (156 miles) the waters of numerous tributaries which rise in the spurs of the volcano of Colima. It is somewhat rapid and has an average flow of 28 cubic meters (989 cubic feet) per second. Its waters are employed to some extent in irrigation, but not so much in this State as in Colima.

The Ameca rises within the State, has a length of more than 55 leagues (143 miles), and empties into the bay of Banderas, on the Pacific coast. It is a fine stream, having an average flow of 20 cubic meters (706 cubic feet) per second, and is capable of being utilized in agriculture.

The Bolaños rises within the State, and after a course of about 48 leagues (125 miles) empties into the Cuitzeo. It has a rapid current, with an average flow of 15 cubic meters (530 cubic feet) per second. It is utilized in agriculture.

Several other streams, with volumes ranging from 2 to 10 meters (71 to 353 cubic feet) per second, are more or less used in agriculture; but the principal use both of these and those designated by name above is in stock-raising. There are also innumerable small streams, tributaries of the larger ones.

The most noteworthy lakes in this State are those of Chapala, Magdalena, Mexcaltitan, Atemanica, Cajititlan, San Marcos, Zacoalco, Atoyac, Sayula, Zapotlan, and Santa Maria del Oro, besides which there are many others, which, although smaller and not so well known, are nevertheless of great utility.

Lake Chapala is 90 kilometers (56 miles) long, and has an average width of about 17 kilometers (about 10½ miles). It is the most important lake in the State, whether considered with reference to the facilities it affords for internal navigation or to its utility in agriculture and stock-raising to the people along its shores; and by means of canals, especially one connecting it with the Ameca River, its waters might be more extensively utilized for both of these purposes. The other lakes mentioned are much smaller than Lake Chapala. With the exception of Lakes San Marcos, Zocoalco, Atoyac, and Sayula, they all have potable waters; and the same is true of the numerous smaller ones not mentioned by name.

There are few permanent irrigation works in the State, mere temporary appliances being generally used to draw off the water for irrigation or for live-stock. The works at Bellavista, executed with great skill by Señor D. Gabriel Castaños, should, however, be mentioned as a noteworthy exception to this rule.

In No. 14 of the series of official publications from which the above information is taken there are reports from several localities in this State, but none referring to any work of importance for irrigation or to any use of water for that purpose except on an insignificant scale.

In No. 16 there are reports from several districts. In the municipality of Atemajac de las Tablas (in the district of the same name) there are four reservoirs, but their chief use is the storage of water power for flouring and saw mills. In the municipality of Tescuitatlan there is a public reservoir known as the Santa Rosa, in which rain-water is stored. Its length is 502 meters and its breadth 260. In the municipality of Tizapan el Alto there is one reservoir—that of Las Cuartas—in which enough water is stored for the irrigation of a small area on one ranch.

Reports are published from many other municipalities, and numerous small streams and springs are referred to as furnishing water for the irrigation of orchards, gardens, or fields. The aggregate area fertilized by their water is quite large, but there are scarcely any among them that have a volume of more than 1 or 2 cubic meters per second, and no important works are reported for making an increased area available to irrigation.

MICHOACAN.

Under date of Ario, March 22, 1886, Señor J. Medal furnishes the department of public works with a brief report on the hydrographic features of this State, which, he says, have never been studied, and are but little known. The principal streams which lie wholly or partly within the limits of the State are the Lerma, the Balsas, the Marques, the Tepalcatepec, the Duero, the Astula, the Apisa, the Rio Grande de Morelia, and the Huetamo.

The Lerma is provided with dams and reservoirs to facilitate irrigation, and several towns or villages and forty farms along that part of the river embraced within the limits of Michoacan avail themselves of its waters to irrigate wheat, maize, chick-peas, &c. In the Duero and the Morelia there are some small dams. The other streams are turned to little account, partly because of the broken character of the districts through which they run, and partly because of the limited extent to which agriculture in those districts is carried on. The volume of water in these streams is very large. The Balsas, for example, empties into the sea with a volume of 132 *bueyes*, 12 *surcos* of water;* and the Marques at a point called the Juntas, before receiving its last tributaries, has a flow of 44 *bueyes*. In the southern districts of the State irrigation is used in the cultivation of sugar-cane, indigo, and rice, each estate having one source or more from which a supply of water is obtained. The water is conveyed to the fields in covered conduits.

The population is generally located near the streams, and there are but few who have occasion to resort to wells. Such wells as there are range from 10 to 20 *varas*† in depth in the case of the deep ones, while the others range from 2 to 10 *varas*.

It is worthy of remark that in the higher and colder parts of the State the springs and fountains are permanent throughout the year and maintain a medium temperature throughout the day. In the hot part of the State the streams are more numerous, but many of them run dry in October, and do not flow again until the end of May. The chief cause of their disappearance is readily found in the rapid evaporation which occurs in such hot climates. According to observations made at Churumuco in May, 1883, a cubic meter of water exposed to a dry, hot atmosphere, the temperature being about 100° Fahr., lost by evaporation 2 to 2½ liters per hour, while observations made at Lake Sirahuen, with a temperature of about 59°, showed a loss of hardly one-fourth of a liter in the same time.

In No. 15 of this series of publications some additional information is furnished in a report from the district of Tacámbaro in this State.

The stream known in different parts of its course as the "Caramecuara," "Las Joyas," and "San Juan" is used for the irrigation of 20 *caballerias* ‡ of land belonging to the different estates through which it flows before uniting with the Tacámbaro; while the latter, which has a volume of 3 *bueyes* in the dry season and an average of 8 *bueyes* during the rainy one, irrigates 6 *caballerias* of farming land, as well as the fields and kitchen gardens near the city of Tacámbaro. The Turivan has an average volume of 4 *bueyes* through the dry season, and in its whole course through the district irrigates 12 *caballerias* of land. The Puruaran, or Caliente, has a volume of 5 *bueyes* and 4 *surcos* from November to June, and from June to November its flow is considerably augmented by the rains. It irrigates about 7 *caballerias*. These four streams, with fourteen smaller ones, none of which irrigate more than a few hundred acres of land, have an aggregate volume of about 26 *bueyes* of water, and serve for the irrigation of an aggregate area of 55 *caballerias* (5,585 acres) of land. A small addition should be made to this total for areas irrigated from springs, ponds, and swamps.

MORELOS.

Señor Teodoro E. Iturbide, under date of March 26, 1886, makes a report, from which the following particulars are taken:

In the district of Coatlan there are three rivers—the Amacusac, the Chalma, and the Tambembe. The Amacusac is formed by the union of the San Geronimo and the Chontalcuatlan, their confluence being a short distance outside of the district. The waters of the San Geronimo are utilized for irrigation on many wheat farms in the district of Villa Guerrero, or Tecualoya. During the rainy season it has a flow of about 35 cubic meters (1236 cubic feet). The Chontalcuatlan, which receives a number of tributaries, furnishes water-power to many small factories, and its waters are utilized to some extent in mining. After watering innumerable orchards and gardens along its banks it still has a flow of 25 cubic meters (883 cubic feet) in the wet season, and from 10 to 12 cubic meters (353 to 424 cubic feet) in periods of drought. The Amacusac, formed by the union of the two rivers last named, has a flow of 60 cubic meters (2,119 cubic feet) during the rainy season, without including freshets, and in time of drought it has somewhat less than half that volume. Thus far but little use has been made of its waters in irrigation except for the orchards immediately along its banks. After receiving the waters of several tributaries this river takes the name of Rio Grande, and still lower, after passing beyond the limits of Morelos and uniting with the Pueblo, it is known as the Mezcala or Balsas until it reaches the sea at Zacatula.

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* The *buey* is a somewhat indefinite expression, meaning a stream of water as large as the body of an ox, while the *surco* is the quantity conveyed in a furrow made for the purpose in irrigating land. Some years after the adoption of the metric system a decree was issued making 6½ liters (a little less than 1.72 gallons) per second the equivalent of the *surco*.

† The *vara* is a measure of about 2 feet 9 inches in length.

‡ A *caballeria* = about 107 acres.

The Chalma is the most important river in the district, not in respect to size, but on account of the fertility which it confers on the many towns and districts through which it flows. It rises in the State of Mexico, rapidly increasing in size as it receives the waters of numerous springs and rivulets, and becoming a considerable stream before entering Morelos. It waters extensive tracts of level lands in the vicinity of the sugar mills of Cocoyotla, Actopan, Santa Cruz, San Gabriel, and the estate of Cuachichinola, and at the same time irrigates the fields in the towns of Coatlan del Rio, Tetecala, Mazatepec, San Miguel Cuantla, Cuachichinola, and Puente de Ixtla. It has a flow of 25 or 30 cubic meters (883 to 1,059 cubic feet) during the rainy season, and 10 to 12 cubic meters (353 to 423 cubic feet) during the dry months.

The Tembembe is scarcely utilized at all in irrigation. Its flow during the wet season equals and often exceeds that of the Chalma, but during the rainless months it runs almost dry.

There is only one dam in the district of Coatlan del Rio. This was constructed in the Tembembe River, at a cost of about $20,000, for the irrigation of the extensive fields of the Miacatlan estate; and it also serves to supply the town of the same name with water. It is considered a meritorious piece of work in respect to its architecture, its extent, and its solid construction. The district being well supplied with water, there are no reservoirs for its storage.

The laws which govern the distribution of water are understood by the writer of the report to be those comprised in the civil code of the federal district and of the Territory of Lower California, this code being in force in Morelos.

OAXACA.

District of Cuicatlan.—Señor F. Villaseñor reports on the different subdivisions of this district, under date of March 27, 1886. A river known as the Rio Grande, which empties into the Papaloapam, flows through this district and furnishes water for irrigation at many points along its course. Its volume in the rainy season amounts to 200 cubic meters per second, or more; but during the dry months it falls to four or five meters. Of its smaller tributaries there are many which dry up during the latter portion of the year, but it also receives a considerable number of permanent streams, most of which are more or less utilized in the irrigation of maize, sugar-cane, or other crops.

District of Tlaxiaco.—Señor Rafael F. Lanza, reports from this district, under date of March 20, 1886. He enumerates many small streams, giving their source, direction, estimated volume, &c., the latter in most cases falling below one cubic meter per second during the dry season. Most of these streams are utilized to some extent in the irrigation of crops, besides furnishing water-power for mills. There are no large rivers in the district.

District of Yautepec.—Señor Augustin R. Arenas reports on this district, under date of March 29, 1886. The most important stream within its limits is the Rio Grande de Tehuantepec, which rises in the mountains of Quiechapa and Mixtepequez, in the district of Mihautlan, and empties into the Pacific 10 or 12 miles from Tehuantepec. The average flow at the lowest estimate is about 5 *bueyes** per second. It is utilized in irrigating sugar-cane and maize at certain points along its course. There are also several smaller streams which are turned to account for the same purpose. Owing to the smallness of the rainfall the streams in this district have greatly diminished in size, and there are no important bodies of water of any kind within its limits, nor have any laws been enacted on the subject of water distribution.

District of Ocampo.—The principal rivers which traverse this district are the Villa Alta and the Rio Mudo. The character of the country is not favorable to irrigation, and the streams which flow through it, though many of them are constant, are not turned to account for that purpose. The same remark will apply to the waters of a number of small lagoons found within its limits.

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*See p. 227.

District of Choapam.—A report from this district dated April 8, 1886, enumerates various streams, but none whose waters are utilized in irrigation. As regards rights to the use of water, the ancient Spanish ordinances in relation to lands and waters are in force.

District of Tuxtepec.—A report from this district enumerates various rivers, lakes, and lagoons, but adds, that no irrigation is needed because of the abundant rainfall. The provisions of the civil code of the federal district, amended in some few particulars, are legally in force under State authority, but in the absence of any need for the appropriation of water, difficulties in regard to water rights seldom arise.

District of Juchitan.—In a report from this district it is stated that there is scarcely any irrigation practiced within its limits, there being comparatively little need of it. A project is, however, mentioned for utilizing the waters of the Astula River for the irrigation of a tract 7 leagues (18.2 miles) in length by 4 leagues (10.4 miles) in breadth on the Piedra Parada estate near Ishuatan. The Astula, which is the principal river in the district, has a volume of 8 cubic meters during the dry season, and its plains are referred to as "wide and fertile."

District of Teposcolula.—Reports from the municipalities in this district enumerate many small streams and springs and some lakes of small extent, but none which are used in irrigation.

Reports from a number of municipalities mention irrigation as practiced on a small scale within their limits. The mayor or president of each municipality annually appoints an officer, whose duty it is to distribute the waters in fair proportion among those having fields or gardens to irrigate.

PUEBLA.

Señor A. Fontecilla, replying to the circular of the minister of public works, writes from Teziutlan under date of March 21, 1886, to the effect that no statistics in regard to water supply have been collected. He mentions, however, such streams as are within his own knowledge, the Chignautla, a creek which empties into the Saint Peter and Saint Paul River, being specified as one whose waters are used in the irrigation of some small areas on the outskirts of Teziutlan. This stream is described as being admirably adapted to the purpose of furnishing power for mills and factories, its volume being almost without change throughout the year, and its descent uniform and sufficiently rapid.

QUERETARO.

Señor Bernabe Loyola, replying to the circular of the minister of public works, writes from Juriquilla under date of March 11, 1886. His report relates only to the neighborhood of Juriquilla, where there are four small and unimportant reservoirs; but he states that he himself is constructing one which will contain 1,100,000 cubic meters of water, and will command a large part of the valley of Queretaro. On an estate to the north of Juriquilla there are two good reservoirs, but they are dependent on the rains for their supply of water, and have only been filled six times in the last twenty-seven years. The largest one, known as the Santa Catarina, is 2,500 meters* long by 900 wide and 6 deep. The other, known as the Pinto, is 1,275 meters long by 600 wide and 4 deep. A reservoir of small size is found on the San Miguelito estate, northwest of Juriquilla. It is of little importance, but serves to irrigate some limited areas of tilled land.

Señor A. M. Veraza, writing from Queretaro under date of April 8, 1886, gives a more general account of the water supplies of the State, enumerating many permanent streams whose waters are used in irrigation, but none having a volume of more than a few cubic meters. He also mentions a number of small lakes and lagoons, with some of the most important springs in the State.

There has been no State legislation especially bearing on the use of water, which is regulated by the civil code, the Spanish laws, and the ancient ordinances of land and water, according to their respective dates.

TAMAULIPAS.

The reports from this State relate only to a few localities and do not embrace accounts of any of its larger rivers. Its situation in the northeastern part of the republic, with the Gulf of Mexico bordering it on the east, renders it comparatively independent of any artificial means of supplying the crops with water.

A report to the State government from the council of Nuevo Laredo mentions the Rio Bravo as the only source of water for live-stock in the dry season. During the rainy season it is subject to heavy floods and overflows the bottom lands along its banks on which the farmers raise sure and abundant crops.

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* The meter=3937. inches.

TLAXCALA.

Señor Carlos Lennox Kennedy, writing from the agricultural agency of the department of public works at San Juan Atoyac, Tlaxcala, under date of April 15, 1886, makes a brief report to the minister of public works on the water supplies of this State. He mentions the Zahuapan and the Atoyac as the only streams deserving the name of rivers. The former, which is tributary to the latter, is utilized between the town of Apetatitlan and its confluence with the Atoyac, by eleven estates, six towns, and a number of small farms, while it also furnishes water-power to several mills and factories. It is, however, but a small stream, its volume during the dry season not exceeding 1½ cubic meters per second, after receiving the waters of many springs and rills.

There is no place of any considerable population on the Atoyac, but it furnishes water for the irrigation of ten estates and the supply of six towns. In the rainy seaosn it is a roaring torrent, swollen by the waters which pour into it from the mountains, but during the dry weather it dwindles to a volume of about 4 cubic meters per second.

In the eastern part of the State reservoirs are used for the storage of rain water, that being the only means by which a reliable supply for man and animals can be secured. These reservoirs vary in size according to the needs of the localities where they are situated.

There has been no legislation in this State to regulate the appropriation of water for irrigation or motive power. The proprietors of land and manufacturing establishments use the waters of the rivers in accordance with the privileges conceded by the colonial government in the original titles to their property; and those who do not enjoy such rights have recourse to the authorities of the municipality controlling the water which they desire to use, and are allowed to take the water needed for irrigation subject to an annual tax, which goes into the municipal treasury.

VERA CRUZ.

Señor José Manuel Jáuregui, writing from Jalapa under date of April 24, 1886, transmits to the minister of public works a report from the chief civil officer of the district of Papantla, who states that the water courses of that district are not utilized in agriculture or in manufactures. In the former no machinery is used, nor is there any resort to irrigation, and when there is a prolonged drought the consequences are severely felt, the agriculturists making no efforts to utilize the waters that are at hand, but contenting themselves with the hope of rain while their crops perish.

Legislation on the subject of water is only rudimentary.

The principal rivers of the district are the Saint Peter and Saint Paul (one river) and the Cazones, both of which are navigable for short distances. No estimate is given as to their volume and no information as to irrigation, either on these streams or their tributaries, within the district.

A return from the district of Acayrican enumerates many small streams, including a number of arroyos which disappear during the dry season, but no mention is made of any use of these waters for irrigation.

A report from Orizaba enumerates various streams, some of which are used to a small extent in irrigation; but the largest (the Ingenio) has a flow of only 5½ cubic meters, while some of the others dwindle during the dry season to less than 1 meter.

From a list of the principal rivers which rise and flow through the State of Vera Cruz, those having a length of 40 leagues (104 miles) or upwards are presented below:

Panuco, Tamesi, Moctezuma, Calabozo, or San Juan, De los Hules, San Pedro, San Marcos, or Cazones, Tecolutla, or S. Pedro and S. Pablo, Mautla, or Rio Frio, Papaloapam, or Quiotepec, Tesechoacan, Zapotla, or San Juan, Blanco, Coatzacoalcos.

ZACATECAS.

Reports have been sent to the ministry of public works from a few localities in this State. One from the municipality of Sain Alto mentions two streams and a number of springs which are used to a considerable extent in irrigation. The larger stream has a course of 6 leagues (about 16 miles) and a volume of 30 *surcos*. As regards water rights, the rule is that the different landed proprietors "take what water they need where their property is crossed by a stream, leaving the rest for others." There is some irrigation from small streams in other municipalities heard from.

A report from Nochistlan mentions a few unimportant rivers and two small reservoirs which serve to irrigate small areas of land; and one from Juchipila mentions a stream from which considerable water is obtained for the irrigation of orchards and gardens along its course, the quantity being increased at one point by a reservoir wherein water is saved for use during the dry season.

HIDALGO.

A report from the agricultural agency in Tianguistengo mentions a few small streams, but gives no account of any use of their waters for irrigation. There are no lakes, swamps, or reservoirs within the jurisdiction of the town named, but numerous rills and brooks are found in all directions.

GENERAL REMARKS.

While the information at hand is presented under the heads of the different States, it does not in any case purport to be exhaustive, and in the case of several States, it will be remembered, only a few localities have been heard from. When all the reports shall have been received the Government of Mexico will be in possession of much valuable material in respect to the hydrographic system of the country and its relation to agriculture and other industries.

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